Eur J Med Res (2008) 13: 517-524 

# Diagnosis and Pre-operative Management of Multiple Injured Patients with Explorative Laparotomy because of Blunt Abdominal Trauma

J. Heyn[1,2], R. Ladurner[1], A. Ozimek[1], D. Bürklein[1], S. M. Huber-Wagner[1], K. K. Hallfeldt[1], T. Mussack[1]

[1]Department of Surgery – city campus, University Hospital Munich (LMU), Nussbaumstr. 20, 80336 Munich, Germany
[2]Department of Anaesthesiology, University Hospital Munich (LMU), Marchioninistr. 15, 81377 Munich, Germany

**Abstract**
*Introduction:* In trauma patients, injury of solid abdominal organs secondary to blunt trauma is a major source of morbidity and mortality. Different diagnostic options such as FAST sonography or CT scan have been described.
*Methods:* Our trauma registry was used to identify multiple injured patients with blunt abdominal trauma during 2001 to 2006. Patient demographics, diagnostic and operative findings, treatment, complications, length of stay and mortality were reviewed.
*Results:* Of 438 multiple injured patients, 58 patients were diagnosed with blunt abdominal trauma. During examination, free fluid or organ injury could be seen in 72.4% during sonography and in 84.3% of the patients who received CT scan, giving a sensitivity of 92% for initial FAST Sonography. Nevertheless, CT scan showed a higher sensitivity in detecting bowel (84%) or mesenteric (75%) injuries, if compared to FAST. 30 (51.7%) of the 58 patients had to undergo laparotomy because of blunt abdominal trauma, giving a laparotomy rate of 6.8% because of blunt abdominal trauma in multiple injured patients.
*Conclusion:* Sonography is the method of choice for initial screening and CT scan in detecting bowel or mesenteric injuries. A large intraperitoneal fluid accumulation during initial sonography in combination with unstable vital signs should lead to an immediate exploratory laparotomy.

*Key words:* Blunt abdominal trauma, multiple injury, radiological diagnostic, laparotomy.

## Introduction

In trauma patients, injury of solid abdominal organs secondary to blunt trauma is a major source of morbidity and mortality. Different diagnostic options such as sonography with or without contrast material, CT scan and diagnostic peritoneal lavage have been described in the literature. FAST (focused assessment with sonography for trauma) seems to be the most useful initial method in an emergency department, especially in patients who are haemodynamic unstable [14, 17, 35].

However, this technique is poor in locating the cause of intra-abdominal fluid accumulation. But CT scan is the diagnostic tool of choice for the detection of intraabdominal injuries, especially those affecting the small bowel and mesentery as they are difficult to diagnose with other diagnostic tools [14, 27].

Multiple injuries in trauma patients often lead to delayed diagnosis and management. Specifically duodenal injuries, which are relatively infrequent, present difficulties in diagnosis and treatment, because of their retroperitoneal location. In cases of intestinal perforation caused by blunt abdominal trauma, delayed diagnosis leads to increased complication rates. Most of these complications are wound infections, wound dehiscence, acute respiratory distress syndrome and sepsis [12, 22].

It is well accepted that laparotomy is the treatment of choice after significant blunt abdominal trauma in haemodynamically unstable patients. Nonoperative management of injuries to the liver, spleen and kidney in haemodynamic stable patients has been demonstrated to be successful in the majority of cases with highest success rates in liver injuries. This conservative management should be exercised with high index of suspicion, if blood transfusion is needed or intraabdominal fluid could be find in sonography or CT [17, 18, 21, 37].

The purpose of this study was to evaluate the usefulness of various modes of diagnosis in multiple injured patients with blunt abdominal trauma. The ability of CT scanning to detect the signs of intraabdominal injury was evaluated and patient management and outcomes were assessed.

## Patients and methods

A list of all multiple trauma patients with blunt abdominal trauma during 2001 and 2006 was generated by the trauma registry. The charts of all these patients were reviewed. Presentation, mechanism of injury, injury grad, diagnostic findings, management and outcome was recorded. All patients who were hemodinamically stable and did not show any indications for operative treatment during FAST or CT scan of the abdomen where treated nonoperatively. Assessment of hemodynamic stability was based on routine vital signs, serum lactate, and base excess measurements. All patients who were hemodinamically stable and did not show any indications for operative treatment dur-

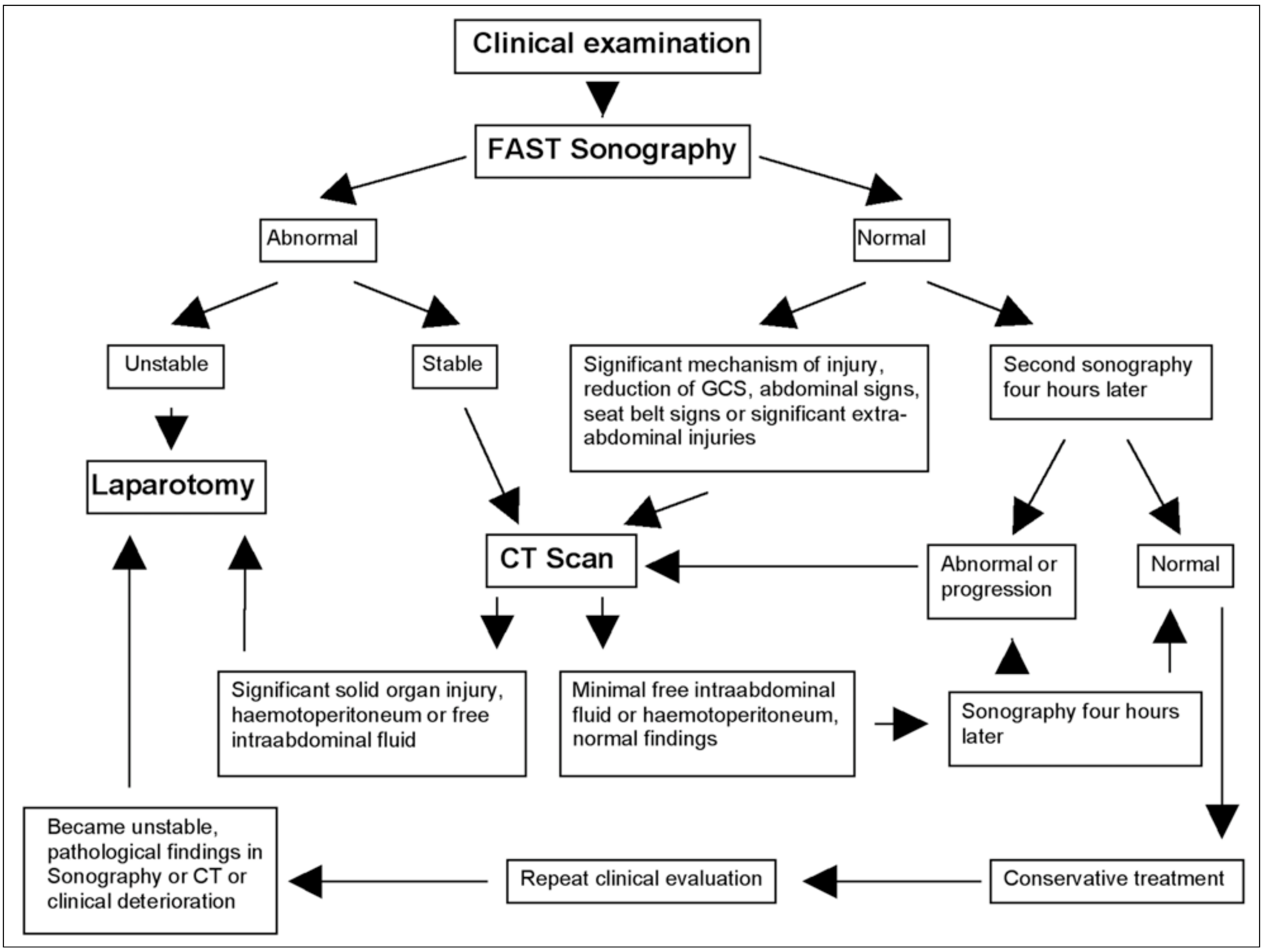


*Fig. 1.* Algorithm for evaluation and management of patients with blunt abdominal trauma - modified after Hughes et al. [16] and Menegaux et al. [20].

ing FAST or CT scan of the abdomen where treated initially nonoperatively.

A standard management protocol for diagnosis was used for all patients after admission (Fig. 1), including a initial FAST sonography (EnVisor C, Philips medical systems, Hamburg, Germany) and spiral CT scanning (Somatom Volume Zoom, Siemens AG, Medical Solutions, Erlangen, Germany) within an hour of arrival at the trauma center for all patients who were haemodynamic stable and had no other indication for immediate abdominal surgery. The characteristic of these patients and their laparotomy findings are summarized in Table 1.

FAST sonography had been performed as described elsewhere [14]. These examinations were performed by sonographers with at least five years of experience of examination. CT scan was performed with 5-mm cuts from the diaphragm through the pelvis. Initial CT scans were interpreted by the trauma service in conjunction with the radiologists. A 120 ml dose of nonionic contrast medium (Peritrast®, Dr. Franz Koehler Chemie GmbH, Alsbach-Haehnlein, Germany) was injected with a rate of 2 ml/sec. The acquisition delay was 60 sec. CT scans were categorized as suspicious if one or more of the following were present: visible discontinuity of the gastrointestinal wall, free fluid in the peritoneal cavity, pneumoperitoneum, focal bowel wall thickening, intramesenteric fluid or haematoma, retroperitoneal haematoma, bowel wall thickening or extravasation of vascular contrast material.

For statistical analyses, sonography was considered to be positive if a parenchyma abnormality that could be consistent with trauma was identified on CT. Positive sonography findings were considered true positive if CT revealed evidence of the parenchyma injury, findings were considered false-positive if the injury was not confirmed on subsequent CT. Negative sonography findings were counted as true negative, if CT findings were negative and the patient had an uneventful clinical course. Findings were considered to be false-negative, if CT scan revealed a parenchyma injury.

The indications for laparotomy were the following: hemodynamic instability, pathological findings on CT scan, positive abdominal signs, positive contrast studies. Major associated injuries of the head, face, thorax, abdomen, axial skeleton, major blood vessels and long bones were recorded. Minor and soft tissue injuries and fractures of the hand or feet were not included.

The time between injury and admission, respectively laparotomy at University Hospital of LMU Munich was calculated. The average time between injury and admission was 67.20 ± 66.84 minutes. In four cases

*Table 1.* Demographics, injury characteristics and labarotory findings in multiple trauma patients with blunt abdominal injury (*$p < 0.05$).

| | Patients with laparotomy | Patients without laparotomy |
|---|---|---|
| Age (yrs) | 45.06 ± 15.54 | 35.75 ± 18.13* |
| ISS | 36.59 ± 17.83 | 30.86 ± 15.78 |
| Injury GCS score | 9.00 ± 18.94 | 11.32 ± 4.92 |
| Admission GCS score | 8.42 ± 5.73 | 10.57 ± 6.78 |
| Time during accident and admission (min) | 68.58 ± 80.83 | 67.04 ± 49.59 |
| CK (mg/dl) | 485.48 ± 817.67 | 312.21 ± 263.54 |
| Lactate (mg/dl) | 3.46 ± 3.19 | 3.23 ± 3.06 |
| Alcohole | 0.41 ± 1.01 | 0.32 ± 0.89 |
| Glucose (mg/dl) | 226.52 ± 172.79 | 189.46 ± 134.23 |
| Hb (mg/dl) | 9.52 ± 2.33 | 11.11 ± 3.09 |
| Operation length (min) | 109.88 ± 57.53 | --- |
| Duration of ICU stay (d) | 23.76 ± 21.04 | 29.04 ± 43.05 |
| Duration of hospital stay (d) | 33.94 ± 27.74 | 34.93 ± 42.56 |
| Mortality (%) | 15.4 | 10.7 |

*Table 2.* Mechanism of injury.

| Mechanism | Patients with laparotomy | Patients without laparotomy |
|---|---|---|
| Motor vehicle accident | 17 (56.7%) | 19 (67.9%) |
| Fall | 4 (13.3%) | 5 (17.9%) |
| Motorcycle crash | 3 (10.0%) | 2 (7.1%) |
| Industrial injury | 2 (6.7%) | --- |
| Pedestrian | 2 (6.7%) | 2 (7.1%) |
| Suicide | 1 (3.3%) | --- |
| Fight | 1 (3.3%) | --- |

*Table 3.* Findings during sonography and CT scan.

| | Number (Percentage) |
|---|---|
| **Findings during FAST (n = 58)** | |
| Free fluid | 30 (51.7%) |
| Organ injury | 18 (31.%) |
| **Findings during CT (n = 51)** | |
| Free fluid in the peritoneal cavity | 32 (62.7%) |
| Organ injury | 33 (64.7%) |
| Extravasation of vascular contrast material | 13 (25.5%) |
| Active mesenteric bleeding | 10 (19.6%) |
| Retroperitoneal haematoma | 8 (15.7%) |
| Pneumoperitoneum | 6 (11.8%) |
| Bowel wall thickening | 3 (5.9%) |
| Intramesenteric fluid or haematoma | 2 (3.9%) |
| **Sonographic findings during second survey (n = 28)** | |
| Free fluid | 10 (35.7%) |
| Organ injury | 24 (85.7%) |

*Table 4.* Associated injuries.

| | **Patients with laparotomy** | **Patients without laparotomy** |
|---|---|---|
| Rib fracture | 9 (30.0%) | 12 (42.9%) |
| Pelvic fracture | 8 (26.7%) | 3 (10.7%) |
| Limb fracture | 8 26.7%) | 11 (39.3%) |
| Vertebral fracture | 7 (23.3%) | 6 (21.4%) |
| Lung contusion | 7 (23.3%) | 5 (17.9%) |
| Pneumothorax | 7 (23.3%) | 16 (57.1%) |
| Craniocerebral trauma | 5 (16.7%) | 4 (14.3%) |
| Pleural effusion | 2 (6.7%) | 1 (3.6%) |

the time until arriving at our hospital was more than 200 minutes. Reasons for delayed arrival were transfer from another hospital or problems with rescue work at the scene of accident.

Sensitivity, specificity, positive predictive value and negative predictive value were calculated for sonography. Analysis was performed using SPSS for Windows (SPSS, Chicago, IL, USA). Normal curve of distribution was revised using Kolmogorov-Smirnov test. Univeriate analysis was performed with student's t-test and chi-squared test where appropriate. A $p < 0.05$ was considered statistically significant. All continuous data are expressed as mean ± SD.

## Results

During the study period between 2001 and 2006 the charts of 438 patients were reviewed, 58 patients (13.3%) were diagnosed with blunt abdominal trauma. In 30 of these 58 patients (51.7%) we had to perform a laparotomy because of bowel or mesenteric injuries. Therefore, laparotomy rate of 438 patients with multiple injuries because of bowel or mesenteric injuries after blunt abdominal trauma was 6.8%. The average age of these patients was 45.06 ± 15.54 years, and the male to female ratio was 3:1. At admission, patients had an average GCS score of 8.42 ± 5.73 points (Table 1). 28 multiple trauma patients with blunt abdominal trauma could be treated non-operative after initial clinical and radiographic examination. The average age of these patients was 35.75 ± 18.13 years with an average GCS score of 10.57 ± 6.78 at admission.

Table 2 summarizes the mechanisms of injury. Motor vehicle accidents were most common in 62.1% of all multiple injured patients with blunt abdominal trauma. Other mechanisms were falls, motorcycle crashes, industrial injuries, pedestrians versus motor vehicles, fights or suicide.

The time between accident and admission at our emergency room was 67.20 ± 66.84 minutes. Clinical examination at admission showed abdominal wall bruising, abdominal distension, pain, tenderness and peritonism signs (data not shown). Laboratory examinations revealed elevated levels of lactate, CK and Glucose in both groups if compared to normal controls (Table 1).

Initial sonography was performed in all patients, while CT scan was done in 51 patients (89.6%). In 7 cases, we do not perform CT scan, because of instability of the patient and/or enormous amounts of free fluid inside the peritoneal cavity. Mean time between admission and initial sonography was 8.19 ± 9.04 minutes and between admission and whole body CT scan was 17.13 ± 9.31 minutes.

Free fluid or organ injury could be seen in 72.4% during sonography and in 84.3% of the patients who received CT scan, giving a sensitivity of 57% and a specificity of 92% for the FAST sonography in detecting free fluid or organ injury, respectively. In all patients without free intra-abdominal fluid during FAST, CT scan also showed no extravasation of contrast material. On the other hand, CT scan showed a higher sensitivity in detecting bowel (84%) or mesenteric (75%) injuries, if compared to FAST. In these cases, CT scan revealed a specific diagnosis (e.g. bowel perforation or mesenteric injury) and FAST revealed only unspecific signs as free abdominal fluid.

During CT scan abdominal organ lesions could be seen in 33 of 51 cases (56.9%). In 17 (33.3%) cases CT scan revealed a rupture of the spleen and in 18 (35.3%) cases a rupture of the liver. An extravasation of vascular contrast material could be found in 13 (25.5%) cases and a retroperitoneal haematoma in 8 patients (15.7%, Table 3).

55 patients had one or more associated significant injury. These injuries are listed in Table 4. Most commonly a pneumothorax could be found. Other associated injuries included fracture of the ribs or limb bones, lung contusion or craniocerebral trauma.

Laparotomy was performed in 30 cases. An abdominal CT scan with diagnostic or suspicious findings was the main reason for laparotomy in 17 (56.7%) cases, followed by haemodynamic instability in 11 cases (36.6%) and respiratory insufficiency in two cases (6.7%). In general, laparotomy was performed within 4 hours after accident in 76.7% of the cases. Laparotomy was delayed more than 4 hours after injury because of assessment and investigation times, management of other life threatening injuries and further clinical observations.

During explorative laparotomy different findings could be made and therefore, different surgical procedures had to be performed. Mesenteric injuries could be found in 21 patients (70.0%), bowel injuries such as perforation, ischemia or contusion was found in 23 patients (76.7%) and both types of injury in 14 patients (46.7%). Bowel perforations could be closed by wound edge debridement and primary closure in minor cases. A segmental bowel resection had to be performed in 12 patients, because of multiple or extended perforations or bowel infarction. In case of spleen rupture, two patients could be treated with primary suture and in three cases a splenectomy had to be done. Second look laparotomy was performed in 13 (43.3%) cases and revealed no additional injuries or complications.

Different complications were seen during and after operation. In 4 (13.3%) cases a haemorrhagic shock occurred. Another 4 patients developed an abdominal compartment syndrome (13.3%) and three patients had a defect of wound healing (10.0%). Interestingly, cholecystitis also occurred in three cases (10.0%) with following cholecystectomy in two of these. Two patients (6.7%) complained about abdominal pain without any organic compound, another two patients (6.7%) developed an abdominal compartment syndrome during their hospital stay and a single patient developed anastomotic insufficiency (3.3%).

Patients who were hemodinamic stable and did not show any suspicious or significant diagnostic findings during FAST or CT scan, non-operative management was performed. In these patients, secondary sonography was done after four hours after FAST to detect any intra-abdominal changes. During this sonography free abdominal fluid could be seen in 10 patients (35.7%) and an organ injury in 24 patients (85.7%) giving a sensitivity of 86% for secondary sonography, if compared to CT-scan. In none of the patients treated non-operative, laparotomy had to be performed during their hospital stay.

Post-operative, the patients stayed for an average of 26.18 ± 32.82 days at ICU. The overall stay at our hospital was 34.41 ± 33.17 days (Table 1) and the 30 day mortality rate was 13.8% (8 patients). Presence of one or more major associated injuries, age, laboratory findings and site of intraabdominal injury were not found to be significant risk factors for intraabdominal injuries related mortality ($p>0.05$).

## Discussion

In 1923, Vance proposed three different mechanisms by which blunt abdominal trauma could lead to injuries of the bowel and mesentery. First, the gastro intestinal tract can be crushed between an object and the rigid skeleton posterior. This mechanism leads to local laceration of the bowel wall and mesentery, mural and mesenteric haematomas, localised devascularisation and full thickness contusion. The second mechanism is rapid deceleration causing shearing forces between fixed and mobile portions of the gastro intestinal tract. Natural points of fixation are the ligament of Treitz, the ileocaecal junction and both ends of the sigmoid. The last mechanism is burst injury, which occurs if loops of intestine are closed off during impact. In these cases, bowels burst when intraluminal pressure exceeds the tensile strength of the bowel wall. In many cases, the described mechanisms will be operating and the type of injury will depend on the relative contribution of each [36, 39].

In up to 75% of the cases, the majority of patients with blunt abdominal trauma are male whose average age is between 34 and 36 years. Motor vehicle accident is the most common reason for blunt abdominal trauma in 69% to 84% of the cases, followed by motorcycle crash in 2% to 14% and falls in 5% to 8%. Least common are assaults or industrial accidents in 4%, bicycle or horse riding accidents in 3% and snowmobile crashes in less than 1% [16-18, 21, 26, 34]. These findings are very similar to our findings, except for the average age of patient.

Interestingly, the patients who underwent laparotomy because of blunt abdominal trauma were about ten years older than the patients who received conservative treatment or were analysed in other series. That could be due to the fact that atherosclerotic changes of the vessels occur in older humans. These changes may be associated with a weakening of the intima in addition to loss of elasticity and compliance and an increased risk for an injury of these vessels [29]. On the other hand, in our study the data of only 58 patients were analyzed. Therefore, we can not exclude that our findings are associated to a smaller number of cases, because some of the other studies had a bigger study population (29 to 1125), which had been analysed [16-18, 21, 26, 34].

Associated extra-abdominal injuries are common and include mostly fractures of the ribs or limbs, head injuries, fractures of the vertebral bodies, pneumothorax, pelvic fractures and vascular injuries. In intra-abdominal cases, the spleen is most commonly affected in up to 27% of patients. Liver injuries can be found in 19%, renal injuries in 13%, pancreatic injuries in 8%, injuries to the diaphragm in 5% and to the bladder in 3%. In our study population, we saw most common bowel perforations and mesenteric injuries. Most reasonable therefore are, that active bleeding leads to free intra-abdominal fluid and bowel perforation to a pneumoperitoneum. Free intra-abdominal fluid and pneumoperitoneum could be easily detected by sonography and/or CT and are reasons for a laparotomy in patients with multiple injuries.

The rate of injuries to the spleen or to the liver was similar to other series. In case of associated injuries, we saw frequent injuries of the ribs or lung. Fractures of the spinal column after blunt abdominal trauma and intraabdominal injury have not been described often in the literature so far. In our study 22.4% of the patients showed injuries of the spinal column. An explanation for these findings could be that patients who have to become laparotomy often have multiple and serious associated injuries which is expressed in an increased Injury Severity Scores [1, 6, 16, 18, 21, 34].

In other studies, ISS of patients with blunt abdominal trauma varies between 13 and 28 and mortality rate was increased when ISS also was elevated [1, 18, 21]. These results are comparable to our findings, because we found a mortality rate of 13.8% and a mean ISS of 36.59 ± 17.83 in the laparotomy group and a mean ISS of 30.86 ± 15.86 in the non-operative group.

Blunt abdominal trauma is an immediate threat to life, which requires rapid diagnosis and treatment. Diagnosis may be difficult in patients presenting a trauma associated with additional distracting injuries or altered mental status from head injuries or drug abuse. In most cases, clinical examination does not provide sufficient information about the extent of abdominal injuries. Typical clinical findings in patients with blunt abdominal trauma are tenderness, distension, diffuse peritonism, abdominal wall bruising, hypotension and tachycardia; but only abdominal wall bruising in clinical examination showed a significant correlation to bowel and mesenteric injuries. Additional diagnostic techniques include diagnostic peritoneal lavage, sonography and CT [5, 11, 14].

Diagnostic peritoneal lavage can reliably detect the presence of intraperitoneal blood and intestinal contents. The reported sensitivity and specificity are more than 90% in detecting intra-abdominal injuries or intraperitoneal bleeding. Unfortunately, retroperitoneal injuries and injuries of the bladder can be detected with a low sensitivity. False positive test may occur in the presence of pelvic fractures. As small volumes of blood may also lead to a positive test, this procedure can not differentiate between injuries which do and do not require operative intervention. Another disadvantage is the invasive nature of the lavage, which is associated with a risk of complication in about 2%. Additional lavage cannot be repeated if initial results are equivocal or the patient's condition changes. Ng et al. suggest in their study diagnostic peritoneal lavage as a delayed diagnostic tool in stable patients using withe blood cell count and enzyme levels to detect hollow viscus injuries. Considering all these disadvantages of diagnostic peritoneal lavage, we do not perform this diagnostic tool at our hospital [13, 24, 25, 32].

Today, sonography has replaced diagnostic peritoneal lavage and is the first step in radiological assessment especially in haemodynamic unstable patients. Different studies showed that FAST examination is a useful method for abdominal trauma. Its main application is the detection of free abdominal fluid, but it is also important in evaluating pleural and pericardial fluid. The FAST protocol includes real-time sonographic scanning of four regions, namely the right upper quadrant with particular attention to the hepatorenal fossa (Morsion's pouch), the left upper quadrant (subphrenic space and splenorenal recess), the pelvis with special attention to the pouch of Douglas, and the pericardium. For detecting free intraperitoneal fluid, the sensitivity of the FAST examination has been described between 31% and 89% with a specificity of 99%. The sensitivity of sonography to detect intraperitoneal fluid is relatively proportional to the amount of fluid in the peritoneal cavity, especially for the inexperienced operator [2, 17, 27].

Sonography examination offers different advantages, because it is non-invasive, portable, rapid, accurate, repeatable and requires no contrast material. A limited risk has been described for patients who are pregnant or have had previous abdominal surgery. One disadvantage includes the inability to determine the exact origin of the free intraperitoneal fluid. It can be also extremely difficult to interpret the findings in obese patients or in patients who show subcutaneous air or excessive bowel gas. The main limitation of sonography is its poor ability to depict parenchyma lesions with a sensitivity between 41% and 46%. In detection of spleen lesions, sensitivity of sonography varies from 27% to 69%. The sensitivity of detecting injuries of the liver varies from 51% to 88% due to its lager size and the easier approach for sonography [8, 17, 27, 28, 30].

Contrast-enhanced sonography is able to analyze resonance signals originated from contrast agents, which allows continuous real-time sonography during vascular perfusion of the contrast agent. Contrast-enhanced sonography permits a better definition of the limits of the lesions and the normal parenchyma. Valentino at al. have recently shown the usefulness of emergency contrast enhanced sonography (duration of examination 4-6 minutes) in stable patients with blunt abdominal trauma. They found an increased sensitivity in the detection of solid organ injuries to 91% [3]. Therefore, it is almost as sensitive as CT in the detection of solid organ injuries and can be a useful tool in the assessment of blunt abdominal trauma. A significant increase in sensitivity to diagnose haemoperitoneum can be also seen, if a secondary sonography of the abdomen is performed four hours after primary diagnostic [2].

CT is the diagnostic test of choice in stable patients with blunt abdominal trauma and provides excellent anatomical detail of the retroperitoneum. Evaluation of the indications of CT scan revealed that alcohol intoxication, mechanism of injury or unreliable examination as only indications for getting a CT scan failed to show abnormal findings. On the other hand, CT scans showed abnormal findings in patients who were intubated or had an abnormal pelvis x-ray. Typical CT signs of bowel or mesenteric injuries are visible discontinuity of the gastrointestinal wall, pneumoperitoneum, focal bowel wall thickening, mural haematoma, pneumatosis, intramesenteric fluid or haematoma, abnormal mural enhancement, extravasation of vascular contrast material, the sentinel clot sign and extravasation of oral contrast material. Sensitivity of CT scans has been described between 80% and 82%, specificity in up to 99% [1, 4, 7, 11, 15, 33].

Oral contrast material has been useful for depicting bowel injuries of the duodenum and the proximal jejunum as well as pancreatic and mesenteric injuries. Stuhlfaut et al. could show that multi-detector row CT without oral contrast material is adequate for depiction of bowel and mesenteric injuries. The evaluated data were comparable to data for single-detector row CT with oral contrast material [33].

Magnet resonance imaging offers some advantages compared to CT, including less nephrotoxic contrast materials and lack of radiation. However, MRI examination of multiple trauma victims is impractical in many hospitals because of difficult patient access, the need of special equipment for anaesthesia and electronic monitoring and lack of rapid access to MR scanning in emergency departments [27].

Although additional examinations as duodenography have been described as diagnostic procedures for blunt abdominal trauma in the literature, duodenography failed to be a useful tool in the diagnosis of blunt abdominal trauma because of its sensitivity of 54% and specificity of 98% [34].

Development of less invasive investigations has provided new challenges in the detection of hollow viscus injuries and changed the way solid organ injuries are managed today. When small amounts of fluid in the peritoneal cavity can be detected by sonography or CT scan, patients could safely be treated without operation. Nonoperative management has become the standard of care for haemodynamically stable patients with blunt injury to liver or spleen with success rates above 80%. In patients who show both spleen and liver injury, a higher failure rate in nonoperative management could be found. Therefore, these patients should be observed with a higher index of clinical suspicion. Different studies report higher failure rates of non operative management of blunt abdominal organ injuries in patients with higher ISS [17, 18, 21, 23]. Miller et al. showed that missed injury is more common in conjunction with liver rather than spleen injury in up to 2.3% [21].

However, a diagnostic problem arises if free fluid can be detected without any solid organ injury and the possibility of hollow viscus or mesenteric injury is raised. In some cases, these findings can be associated with pelvic fracture as a source of the fluid. Several studies evaluated CT scan findings of unexplained free fluid in the peritoneal cavity to determine the patients who require laparotomy. The results of these studies are controversial. Rates between 19% and 54% for therapeutic laparotomy have been reported in patients who presented free fluid on CT scan. In our study, we had a therapeutic laparotomy rate of 93.3% in patients who showed free fluid in the peritoneal cavity. These findings are comparable with those of other series in which therapeutic laparotomy was performed in 94% to 95% [3, 9, 10, 25].

The dilemma that surgeons face is how to avoid missed injuries while minimizing unnecessary laparotomy. Subsequent studies demonstrated the advantages of laparoscopy in patients with penetrating abdominal trauma. There are very few studies analysing the role of laparoscopy after blunt abdominal trauma [19, 31].

Advantages of laparoscopy include reduced morbidity, shortened length of stay and a reduction of negative laparotomy rates especially in patients with thoracoabdominal and tangential injuries. However, relevant injuries went undetected in 1% of all laparoscopies, particularly after blunt trauma affecting solid organs or hollow viscus. Mathonnet et al. could show that laparoscopy established the diagnosis of small bowel injury after blunt abdominal trauma in haemodynamically stable patients by showing either direct signs of perforation or indirect signs, such as free fluid. 40% of the patients who underwent laparoscopy were entirely treatable by this operating procedure [19, 31, 38].

Mesenteric injuries are rare and often difficult to diagnose because of its non specific signs. In cases of large defects which compromise the perfusion of the intestine, abdominal pain, tenderness, distension and compromised bowel sound can be detected. Missed or delayed diagnosis often leads to haemorrhage and peritonitis which cause increased morbidity. In many cases, mesenteric lesions often coexist with other injuries that make the patient's condition more serious and send them to the operating room without delay [40].

## Conclusion

Sonography is the method of choice for initial screening for initial screening for free fluid in the peritoneal cavity and parenchyma injury. A large intraperitoneal fluid accumulation during initial sonography in combination with unstable vital signs should lead to an immediate exploratory laparotomy in patients with blunt abdominal trauma.

CT scan has several advantages over sonography and is currently unsurpassed for the detection of blunt abdominal injuries of parenchymal abdominal organs.

This project was kindly supported by Nycomed Deutschland GmbH, Moltkestr. 4, 78467 Konstanz, Germany.

## References

1. Beck D, Marley R, Salvator A, et al. Prospective study of the clinical predictors of a positive abdominal computed tomography in blunt trauma patients. J Trauma 2004; 57:296-300.
2. Blackbourne LH, Soffer D, McKenney M, et al. Secondary ultrasound examination increases the sensitivity of the FAST examen in blunt trauma. J Trauma 2004; 57:934-8.
3. Brasel KJ, Olson CJ, Stafford RE, et al. Incidence and significance of free fluid on abdominal computed tomographic scan in blunt trauma. J Trauma 1998; 44: 889-92.
4. Brody JM, Leighton DB, Murphy BL, et al. CT of blunt bowel and mesenteric injury: typical findings and pitfalls in diagnosis. Radiographics 2000; 20:1525-36.
5. Brown MA, Sirlin CB, Hoyet DB, et al. Screening ultrasound in blunt abdominal trauma. J Intensive Care Med 2003; 18:253-60.
6. Bulinski P, Bachulis B, Naylor DF Jr, et al. The changing face of trauma management and its impact on surgical resident training. J Trauma 2003; 54:161-3.
7. Butela ST, Federle MP, Chang PJ, et al. Performance of CT in detection of bowel injury. AJR Am J Roentgenol 2001; 176:129-35.
8. Chong CF, Wang TL, Chang H. Evaluation of blunt abdominal trauma: current practice in Taiwan. Emerg Med J 2005; 22:113-5.
9. Cunningham MA, Tyroch AH, Kaups KL, et al. Does free fluid on abdominal computed tomographic scan after blunt trauma require laparotomy? J Trauma 1998; 44:599-602.
10. Eanniello VC 2nd, Gabram SG, Eusebio R, et al. Isolated free fluid on abdominal computerized tomographic scan: an indication for surgery in blunt trauma patients? Conn Med 1994; 58:707-10.
11. Elton C, Riaz AA, Young N, et al. Accuracy of computed tomography in the detection of blunt bowel and mesenteric injuries. Br J Surg 2005; 92:1024-8.
12. Fakhry SM, Brownstein M, Watts DD, et al. Relatively short diagnostic delays (<8 hours) produce morbidity and mortality in blunt small bowel injuries: an analysis of time to operative intervention in 198 patients from a multicenter experience. J Trauma 2000; 48:408-15.
13. Fryer JP, Graham TL, Fong HM, et al. Diagnostic peritoneal lavage as an indicator for therapeutic surgery. Can J Surg 1991; 34:471-6.
14. Giuseppetti GM, Diego S, Argalia G, et al. Screening US and CT for blunt abdominal trauma: A retrospective study. Eur J Radiol 2005; 56:97-101.

15. Hanks PW, Brody JM. Blunt injury to mesentery and small bowel: CT evaluation. Radiol Clin North Am 2003; 41:1171-82.
16. Hughes TM, Elton C, Hitos K, et al. Intra-abdominal gastrointestinal tract injuries following blunt trauma: the experience of an Australian trauma centre. Injury 2002; 33:617-26.
17. Ma O, Kefer MP, Stevison KF, et al. Operative versus nonoperative management of blunt abdominal trauma: Role of ultrasound measured intraperitoneal fluid levels. Am J Emerg Med 2001; 19:284-6.
18. Malhotra AK, Latifi R, Fabian TC, et al. Multiplicity of solid organ injury: influence on management and outcomes after blunt abdominal trauma. J Trauma 2003; 54:925-9.
19. Mathonnet M, Peyrou P, Gainant A, et al. Role of laparoscopy in blunt perforations of the small bowel. Surg Endosc 2003; 17:641-5.
20. Menegaux F, Tresallet C, Gosgnach M, et al. Diagnosis of bowel and mesenteric injuries in blunt abdominal trauma: a prospective study. Am J Emerg Med. 2006; 24:19-24.
21. Miller PR, Croce MA, Bee TK, et al. Associated injuries in blunt solid organ trauma: implications for missed injury in nonoperative management. J Trauma 2002; 53:238-44.
22. Morales CH, Villegas MI, Villavicencio R, et al. Intra-abdominal infection in patients with abdominal trauma. Arch Surg 2004; 139:1278-85.
23. Myers JG, Dent DL, Stewart RM, et al. Blunt splenic injuries: dedicated trauma surgeons can achieve a high rate of nonoperative success in patients of all ages. J Trauma 2000; 48:801-6.
24. Nagy KK, Roberts RR, Joseph KT, et al. Experience with over 2500 diagnostic peritoneal lavages. Injury 2000; 31:479-82.
25. Ng AK, Simons RK, Torreggiani WC, et al. Intra-abdominal free fluid without solid organ injury in the blunt abdominal trauma: an indication for laparotomy. J Trauma 20002; 52:1134-40.
26. Ozturk H, Onen A, Otcu S, et al. Diagnostic delay increases morbidity in children with gastrointestinal perforation from blunt abdominal trauma. Surg Today 2003; 33:178-82.
27. Poletti PA, Wintermark M, Schnyder P, et al. Traumatic injuries: role of imaging in the management of the polytrauma victim (conservative expectation). Eur Radiol 2002; 12:969-78.
28. Richards JR, McGahan JP, Simpson JL, et al. Bowel and mesenteric injury: evaluation with emergency abdominal US. Radiology 1999; 211:399-403.
29. Roth SM, Wheeler JR, Gregory RT, et al. Blunt injury of the abdominal aorta: a review. J Trauma 1997; 42:748–55.
30. Rothlin MA, Naf R, Amgwerd M, et al. Ultrasound in blunt abdominal and thoracic trauma. J Trauma 1993; 34:488-95.
31. Simon RJ, Rabin J, Kuhls D. Impact of increased use of laparoscopy on negative laparotomy rates after penetrating trauma. J Trauma 2002; 53:297-302.
32. Sozuer EM, Akyurek N, Kafali ME, et al. Diagnostic peritoneal lavage in blunt abdominal trauma victims. Eur J Emerg Med 1998; 5:231-4.
33. Stuhlfaut JW, Soto JA, Lucey BC, et al. Blunt abdominal trauma: performance of CT without oral contrast material. Radiology 2004; 233:689-94.
34. Timaran CH, Daley BJ, Enderson BL. Role of blunt abdominal trauma in the diagnosis of blunt duodenal injuries. J Trauma 2001; 51:648-51.
35. Valentino M, Serra C, Zironi D, et al. Blunt abdominal trauma: emergency contrast-enhanced sonography for detection of solid organ injuries. AJR Am J Roentgenol 2006; 186:1361-7.
36. Vance BM. Traumatic lesions to the intestine caused by non-penetrating blunt force. Arch Surg 1923; 7:197-212.
37. Velmahos GC, Toutouzas KG, Radin R, et al. Nonoperative treatment of blunt injuries to solid abdominal organs: a prospective study. Arch Surg 2003; 138:844-51.
38. Villavicencio RT, Aucar JA. Analysis of laparoscopy in trauma. J Am Coll Surg 1999; 189:11-20.
39. Wisner DH, Chun Y, Blaisdell FW. Blunt intestinal injury. Keys to diagnosis and management. Arch Surg 1990; 125:1319-23.
40. Xeropotamos NS, Nousias VE, Ioannou HV, et al. Mesenteric injury after blunt abdominal trauma. Eur J Surg 2001; 167:106-9.

*Received: November 28, 2007 / Accepted: June 12, 2008*

*Address for correspondence:*
Jens Heyn, MD
Department of Surgery
University Hospital Munich – city campus
Nussbaumstrasse 20
80336 Munich
Germany
Phone: +49-89-5160-2511
Fax: +49-89-5160-5482
Email: Jens.Heyn@med.uni-muenchen.de