Part 4. Clinical Practice Guideline for Surveillance and Imaging Studies of Trauma Patients in the Trauma Bay from the Korean Society of Traumatology

Sung Wook Chang, M.D.1*, Kang Kook Choi, M.D.2*, O Hyun Kim, M.D., Ph.D.3, Maru Kim, M.D., Ph.D.4, Gil Jae Lee, M.D., Ph.D.2*,
Korean Society of Traumatology (KST) Clinical Research Group

1Department of Thoracic and Cardiovascular Surgery, Trauma Center, Dankook University Hospital, Cheonan, Korea
2Department of Traumatology, Gachon University College of Medicine, Incheon, Korea
3Department of Emergency Medicine, Yonsei University Wonju College of Medicine, Wonju, Korea
4Department of Trauma Surgery, Uijeongbu St. Mary’s Hospital, College of Medicine, The Catholic University of Korea, Uijeongbu, Korea

The following recommendations are presented herein: All trauma patients admitted to the resuscitation room should be constantly (or periodically) monitored for parameters such as blood pressure, heart rate, respiratory rate, oxygen saturation, body temperature, electrocardiography, Glasgow Coma Scale, and pupil reflex (1C). Chest AP and pelvic AP should be performed as the standard initial trauma series for severe trauma patients (1B). In patients with severe hemodynamically unstable trauma, it is recommended to perform extended focused assessment with sonography for trauma (eFAST) as an initial examination (1B). In hemodynamically stable trauma patients, eFAST can be considered as the initial examination (2B). For the diagnosis of suspected head trauma patients, brain computed tomography (CT) should be performed as an initial examination (1B). Cervical spine CT should be performed as an initial imaging test for patients with suspected cervical spine injury (1C). It is not necessary to perform chest CT as an initial examination in all patients with suspected chest injury, but in cases of suspected vascular injury in patients with thoracic or high-energy damage due to the mechanism of injury, chest CT can be considered for patients in a hemodynamically stable condition (2B). CT of the abdomen is recommended for patients suspected of abdominal trauma with stable vital signs (1B). CT of the abdomen should be considered for suspected pelvic trauma patients with stable vital signs (2B). Whole-body CT can be considered in patients with suspicion of severe trauma with stable vital signs (2B). Magnetic resonance imaging can be considered in hemodynamically stable trauma patients with suspected spinal cord injuries (2B).

Keywords: Diagnostic imaging; Practice guideline; Multiple trauma
Based on the revised recommendations, the final recommendations were confirmed after collecting opinions from trauma experts, experts from the Korean Society of Traumatology, and research method experts using the Delphi technique (Table 1).

**WHAT BIOLOGICAL SIGNS SHOULD BE MONITORED IN TRAUMA PATIENTS IN THE RESUSCITATION ROOM?**

**Recommendation**

All trauma patients admitted to the resuscitation room should be constantly (or periodically) monitored for parameters such as blood pressure, heart rate, respiratory rate, oxygen saturation, body temperature, electrocardiography (ECG), Glasgow Coma Scale (GCS), and pupil reflex (1C).

**Evidence review or evidence summary**

Franklin et al. [1] showed that about 50% of patients with hypotension before and after presenting to the emergency room required emergency surgery or hospitalization in the intensive care unit (ICU). In addition, Tinkoff and colleagues reported that in hypotensive patients after trauma, the overall mortality rate was 24 times higher, ICU admission was seven times higher, and emergency operations were 1.6 times more common than in normotensive patients [2]. Henry [3] of the New York State Trauma Registry reported a mortality rate of 32.9% in trauma patients with systolic blood pressure less than 90 mmHg, and 28.8% in trauma patients with respiratory rates of fewer than 10 or more than 29 breaths per minute.

ECG monitoring is essential for all severe trauma patients. In particular, ECG monitoring is necessary to discriminate cardiac arrest that may require defibrillation in patients whose pulse is not palpable. In addition, it can be used as a basic test in patients who are likely to have complications of heart damage due to blunt injury [4-6]. Fildes et al. [7] reported that 74 trauma patients with no underlying heart disease, hemodynamic stability, and a normal initial ECG did not develop cardiac complications. It was reported that 184 children who suffered blunt heart damage, but showed normal ECG in the emergency room, also did not develop complications. In a meta-analysis of 41 studies, it was found that patients with abnormal ECG at hospitalization were more likely to experience complications requiring treatment [7]. Complications occurred in 13 of 133 patients with suspected blunt heart damage, but no complications were observed in patients with a normal initial ECG [8]. In a study by Miller et al. [9], four of 172 patients had complications requiring treatment, and those four patients had abnormal initial ECG readings. In addition, Wisner et al. [10] reported complications in four of 95 patients with suspected blunt heart damage, and only one of those four patients showed a normal ECG at the time of admission.

Measurement of oxygen saturation is also essential in patients with multiple traumas. Oxygen saturation is especially important in patients experiencing cardiac arrest, in whom the oxygen saturation waveform can be lost.

The only clinical symptoms that can predict the prognosis of head-injured patients are enlarged fixed pupils and a low GCS. These two findings are associated with poor treatment outcomes. Therefore, it is necessary to detect deterioration of the patient’s consciousness early through repeated confirmation of neurological findings [11-13].

In addition, end-tidal CO\(_2\) (EtCO\(_2\)) monitoring or securing arterial cannulation can be used to monitor trauma patients admitted to the resuscitation room. The reasons are as follows [14]:

1) EtCO\(_2\) is important for monitoring multiple trauma patients, especially since a sudden drop of EtCO\(_2\) occurs in cases of sudden cardiac arrest.

2) More than 7% of tracheal intubation attempts have been reported to enter the esophagus. Therefore, auscultation and EtCO\(_2\) partial pressure monitoring are essential to confirm the successful and proper placement of the tracheal tube.

3) Early cannulation of the femoral artery for continuous blood pressure monitoring is an objective method for diagnosing cardiac arrest and confirming the effectiveness of resuscitation in an emergency department. However, intraarterial cannulation should not interfere with or delay resuscitation.
Since all the recommended surveillance items are implemented in the majority of emergency departments in Korea, there will be no difficulty in accepting and applying them as guidelines for monitoring trauma patients in the resuscitation room.

In addition, many hospitals are already evaluating the appropriateness of the location of tracheal intubation by monitoring the partial pressure of EtCO₂ after intubation. Therefore, the basis for its acceptance and applicability is sufficient. Furthermore, since the majority of hospitals in Korea already secure an arterial line, the likelihood of acceptance and application is considered sufficient.

**IS THE TRAUMA SERIES CLINICALLY BENEFICIAL COMPARED TO OTHER IMAGING TESTS FOR THE INITIAL PRIMARY EVALUATION IN SEVERE TRAUMA PATIENTS?**

**Recommendation**
Simple chest radiography (chest AP) and pelvic radiography (pelvic AP) should be performed as the standard initial trauma series for severe trauma patients (1B).
raphy (pelvic AP) should be performed as the standard initial trauma series for severe trauma patients (1B).

**Evidence review or evidence summary**

Three guidelines were reviewed to determine the recommended initial emergency radiographic imaging protocol for patients with severe trauma. In the American College of Radiology (ACR) appropriateness criteria, simple chest radiography is recommended for patients with high-energy mechanisms or hemodynamic instability [15]. The National Institute for Health and Care Excellence (NICE) guideline recommends simple chest and pelvic radiography when hemodynamically unstable patients do not respond to fluid therapy [16]. The S3 guideline recommends performing simple chest radiography, pelvic radiography, and C-spine lateral imaging in the emergency room [17].

In the process of developing this guideline, seven studies were examined to determine the value of performing computed tomography (CT) scans. Two of those seven studies suggested that CT scans should be minimized when simple chest radiography shows normal findings [18,19], while three studies reported that performing a CT scan is invaluable regardless of the results of the chest X-ray [20-22]. In addition other studies have suggested that CT scans should be performed selectively depending on the patient’s condition [23]. Five studies were examined to determine the value of performing pelvic X-rays, of which two recommended performing pelvic X-rays to diagnose pelvic bone fractures, while three recommended omitting pelvic X-rays if a CT scan can be performed [24-28]. Lastly, three studies were examined to determine the value of performing C-spine lateral imaging, and two of these three papers recommended cervical spine CT as a screening test for cervical spine injury [29-31]. In these studies, cervical lateral radiography was determined to have little diagnostic value.

**Acceptability and applicability**

The trauma series can be applied in Korea for patients who are hemodynamically unstable and do not respond to fluid therapy, for whom mobile imaging is required. However, consideration should be given for cases in which immediate or mobile imaging is not possible depending on hospital circumstances.

### IN PATIENTS WITH SEVERE TRAUMA, IS THE EXTENDED FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA (EFAST) CREDIBLE AND CLINICALLY USEFUL AS AN INITIAL IMAGING TOOL?

** Recommendation**

1. In patients with severe hemodynamically unstable trauma, it is recommended to perform eFAST as an initial examination (1B).
2. In hemodynamically stable trauma patients, eFAST can be considered as the initial examination (2B).

**Evidence review or evidence summary**

Three guidelines were selected to assess the viability of eFAST in this study [15-17]. The ACR appropriateness criteria recommend FAST/eFAST in hemodynamically unstable patients and patients with high-energy injuries. The NICE and S3 guidelines recommend limited use of FAST/eFAST in situations where CT cannot be performed.

In addition to these three guidelines, 11 other studies were reviewed. In trauma patients, FAST is widely accepted as a means to search for free fluids in the abdominal cavity and pericardium. Furthermore, eFAST is widely accepted as a means to search for pneumothorax or hemothorax [32-34]. However, there are conflicting reports on the recommended use of FAST/eFAST as a screening test for blunt abdominal injuries [32-35]. In one study, FAST/eFAST was recommended even in hemodynamically stable patients [36]. In another study, it was suggested that the use of FAST/eFAST was appropriate in chest penetrating injuries, but there was no benefit in case of abdominal penetrating injuries [37].

**Acceptability and applicability**

This recommendation is applicable. However, it is necessary to consider the application of FAST/eFAST fees.
WHAT IS THE APPROPRIATE IMAGING TEST FOR SUSPECTED HEAD TRAUMA PATIENTS?

Recommendation
For the diagnosis of suspected head trauma patients, brain CT should be performed as an initial examination (1B).

Evidence review or evidence summary
Two guidelines were selected to study the initial imaging process for patients with suspected head trauma. The ACR appropriateness criteria recommend CT as a means of initial imaging for head trauma patients, and for patients with minor brain injury, it is recommended that clinicians decide whether to proceed with the examination according to guidelines such as New Orleans Criteria (NOC), Canadian CT Head Rules (CCHR), and National Emergency X-ray Utilization Study (NEXUS)-II [15]. Korean clinical imaging guidelines recommend CT or magnetic resonance imaging (MRI) for head trauma patients. In children, CT is recommended according to clinical criteria [38].

In addition to the two guidelines, nine additional papers were further reviewed. Neuroimaging plays a crucial role in detecting traumatic brain injury and determining whether immediate treatment is needed. The GCS is commonly used to classify traumatic brain injuries. CT is a fast and effective imaging test with high sensitivity to detect the lump effect, size and arrangement of the ventricle, fracture, and intracranial hemorrhage. MRI is not recommended as an initial imaging test due to its limitations in terms of time and location [39-41]. NOC, CCHR, and NEXUS-II are representative guidelines describing indications for CT. Other studies are being conducted to prevent the abuse and misuse of CT for minor head injuries [42-44]. Non-contrast CT is recommended for patients with moderate to severe head trauma [45-47].

Acceptability and applicability
Brain CT without intravenous contrast is applicable in Korea. However, it is necessary to consider insurance coverage for the usage of brain CT without simple imaging.

IS CERVICAL SPINE CT (C-SPINE CT) CLINICALLY USEFUL AS AN INITIAL IMAGING TEST FOR PATIENTS WITH SUSPECTED CERVICAL SPINE INJURY?

Recommendation
C-spine CT should be performed as an initial imaging test for patients with suspected cervical spine injury (1C).

Evidence review or evidence summary
Two treatment guidelines were reviewed to determine whether C-spine CT should be performed for patients with a suspected cervical spine injury. The ACR appropriateness criteria recommend C-spine CT as an initial imaging test for patients with high-risk clinical criteria (NEXUS or CCR) [15]. In the S3 guidelines, C-spine CT is recommended for patients who have sustained severe trauma injuries who have been hemodynamically stabilized before exiting the ICU. It is also recommended that all patients with suspicion of a cervical spine injury should undergo simple cervical images. If any abnormalities are found on simple images, C-spine CT is recommended [17].

In addition to the two guidelines, four additional studies were reviewed. For patients with suspected cervical spine injury, simple cervical radiography was changed to CT. One study reported that the accuracy of diagnosis through CT was significantly higher than that of diagnosis using simple cervical spine radiography [48]. Conflicting findings have been reported regarding whether CT is sufficient or MRI should be performed additionally [49-51].

Acceptability and applicability
In patients with suspected cervical spine damage, performing C-spine CT is preferable over simple imaging. Currently, it is believed that CT scans are possible at most emergency centers in Korea, and domestic acceptance is considered sufficient.
IN PATIENTS WITH SUSPECTED CHEST INJURY, IS CHEST CT CLINICALLY USEFUL AS AN INITIAL IMAGING TEST?

Recommendation
It is not necessary to perform chest CT as an initial examination in all patients with suspected chest injury, but in cases of suspected vascular injury in patients with thoracic or high-energy damage due to the mechanism of injury, chest CT can be considered for patients in a hemodynamically stable condition (2B).

Evidence review or evidence summary
Three guidelines were reviewed to determine the validity of performing chest CT in chest trauma patients. All three guidelines recommend contrast-enhanced chest CT for patients with high-energy injuries, patients responding to resuscitation, or patients who are hemodynamically stable (in the case of the NICE guidelines) [15-17]. However, the ACR appropriateness criteria recommend that chest CT can be excluded depending on clinical findings [15]. The NICE guideline recommends simple portable chest imaging and eFAST as the initial imaging workup for hemodynamically unstable patients or patients with severe respiratory difficulties [16].

In addition to these three medical guidelines, six other studies were reviewed. In the diagnosis of chest trauma, contrast-enhanced chest CT is becoming more standardized than simple chest imaging [52,53]. Some studies have recommended contrast-enhanced chest CT as a test for chest vascular injury in cases of chest trauma [53-56]. Furthermore, it has been recommended that chest CT be divided into arterial and venous phases [56]. It has also been reported that chest CT significantly improved the diagnosis of diaphragm injuries [57].

Acceptability and applicability
In all patients suspected to have chest trauma, the universal application of chest CT is disadvantageous in terms of both cost and exposure to radiation. Its application in Korea seems limited, but its acceptance could be appropriate.

IS IT DIAGNOSTICALLY USEFUL TO PERFORM ABDOMINAL CT IN PATIENTS WITH SUSPECTED ABDOMINAL TRAUMA WITH STABLE VITAL SIGNS?

Recommendation
CT of the abdomen is recommended for patients suspected of abdominal trauma with stable vital signs (1B).

Evidence review or evidence summary
Early diagnosis and treatment are important in severe trauma patients. In a study by Liu et al. [58] of 55 hemodynamically stable patients, the sensitivity, specificity, and accuracy of abdominal CT were 97.2%, 94.7%, and 96.4%, respectively. In terms of accuracy, abdominal CT was superior to abdominal ultrasonography (92.7%) and diagnostic peritoneal lavage (94.5%). Therefore, abdominal CT has diagnostic superiority compared to abdominal ultrasonography or diagnostic abdominal lavage for detecting retroperitoneal injuries and has the advantage of providing additional information on spinal or pelvic trauma [58,59].

In a study of 372 hemodynamically stable patients with abdominal blunt injuries, FAST had a sensitivity of 42% and a specificity of 98%, which was insufficient as a screening test for intra-abdominal organ damage [60]. Therefore, in hemodynamically stable patients with abdominal blunt injuries, abdominal CT is necessary to make an accurate diagnosis.

Traditionally, laparotomy has been the main treatment for hemodynamically stable patients with abdominal penetrating injuries. However, laparotomy is being performed more selectively depending on the patient’s injuries. Studies that applied selective laparotomy in hemodynamically stable patients with abdominal wounds involving penetration from the anterior aspect, wounds from the back, and solid organs consistently reported successful results [61,62]. In addition to hemodynamic stability, these studies suggested that another prerequisite for selective laparotomy is the absence of evidence of peritoneal signs on physical examination and intestinal injuries on abdominal CT. Therefore, abdominal CT is considered necessary for hemodynamically stable patients with abdominal injuries.

In hemodynamically stable patients with suspected ab-
dominal trauma and decreased mentality, abdominal CT has been reported to diagnose hidden abdominal trauma and lower the mortality rate [63,64]. Negative results on abdominal CT show very high specificity for excluding abdominal damage, shortening the hospital stay for follow-up [65].

Acceptability and applicability
The recommendations presented above are applicable and acceptable.

IS IT DIAGNOSTICALLY USEFUL TO PERFORM ABDOMINAL CT IN PATIENTS WITH SUSPECTED PELVIC TRAUMA WITH STABLE VITAL SIGNS?

Recommendation
CT of the abdomen should be considered for suspected pelvic trauma patients with stable vital signs (2B).

Evidence review or evidence summary
On physical examination, the specificity of the diagnosis of unstable pelvic fractures is high in patients with pelvic trauma, but the sensitivity is very low, ranging from 8% to 44% [66,67]. When comparing simple radiographs and CT, one study found that the diagnosis rate of pelvic fractures by simple radiographs was 66%, which was significantly lower than that of 86% using CT [68]. These findings are consistent, and researchers have often argued that if CT is performed, simple radiographs of the pelvis are unnecessary [26,27,69].

In pelvic trauma, the most important initial evaluation is finding signs of bleeding. According to Berg et al. [68], 73% of contrast leakage seen on CT corresponds to significant hemorrhage seen on angiography. However, since CT often shows negative findings in patients with contrast leakage on angiography, the effectiveness of CT in diagnosing bleeding from pelvic trauma has been debated [70,71]. In a study on the effectiveness of FAST in pelvic trauma, the FAST diagnosis of pelvic bleeding showed a sensitivity of 26% and a specificity of 96%, indicating that negative FAST findings did not exclude bleeding in the pelvic cavity [72].

Pelvic fractures are often accompanied by damage to organs in the abdominal cavity, and solid organ and intestinal damage has been reported in 11% and 4.5% of cases, respectively [73]. Since intestinal injury is an immediate indication for open abdominal surgery, the treatment of choice changes considerably depending on the results of CT. In addition, pelvic trauma is often accompanied by damage to the urinary system such as the bladder and urethra, and according to one report, 6% of all pelvic trauma cases were accompanied by damage to the genitourinary system [74]. In a 10-year study of 54 bladder injuries, 79.8% of patients were found to have a pelvic fracture [75]. Most bladder injuries associated with pelvic trauma are extra-abdominal injuries (80%). For intraperitoneal injuries, the treatment method can be determined by laparotomy [72].

In summary, CT in hemodynamically stable pelvic trauma patients is the best test so far for diagnosing trauma to the pelvic bone. Secondly, with the exception of angiography, CT is the best test for diagnosing intrapelvic bleeding. Thirdly, CT is an excellent test for organ damage in the abdominal cavity/pelvic cavity. It can be used as a screening test for diagnosing and determining the treatment for intestinal or urinary system damage.

Acceptability and applicability
The recommendations presented above are applicable and acceptable.

IS IT DIAGNOSTICALLY USEFUL TO PERFORM WHOLE-BODY CT IN PATIENTS WITH SUSPECTED SEVERE TRAUMA WITH STABLE VITAL SIGNS?

Recommendation
Whole-body CT can be considered in patients with suspicion of severe trauma with stable vital signs (2B).

Evidence review or evidence summary
Severe trauma patients often have multiple traumatic injuries. CT of the head, chest, abdomen, pelvis, and spine in patients with stable vital signs is a powerful test that can determine the treatment options. The S3 guideline, the
Eastern Association for the Surgery of Trauma guideline, and the NICE guideline recommend performing CT as an initial imaging test. Although whole-body CT is thought to yield many advantages, such as shortening the time for the diagnosis and ultimately improving the prognosis, the evidence is insufficient [16,17,75].

In a large cohort study of 1,696 patients at 14 hospitals in France by Matlock et al. [76], the 30-day mortality rate of the whole-body CT group was 16%, which was significantly lower than that of the control group. In Germany, a study using the trauma registry also showed a higher survival rate in the whole-body CT group than in the control group [77]. The only randomized controlled study of whole-body CT to date is the REACT-2 trial [78]. In this study, which enrolled 1,403 patients, the examinations were completed more quickly in the whole-body CT group (30 vs. 37 minutes). However, there was no difference in the mortality rate. As research results may differ across institutions, follow-up studies are needed.

An important consideration regarding whole-body CT is the radiation dose. Although the radiation dose was different between the whole-body and selective CT groups in the REACT-2 study, the difference was not significant [78]. There are several advantages of performing whole-body CT in terms of the radiation dose. The first is that the radiation dose can be significantly reduced if the test is conducted efficiently. The second is that a whole-body CT can reduce the need for further CT scans in the future. The third is that different protocols and indications for performing partial CT can expose patients to additional doses of radiation. Further follow-up studies are needed.

In summary, whole-body CT has the advantage of shortening the examination time. It is recommended that whole-body CT should be performed on patients suspected of severe trauma with stable vital signs.

Acceptability and applicability
The recommendations presented above are applicable and acceptable.

IN HEMODYNAMICALLY STABLE PATIENTS WITH SUSPECTED SPINAL CORD INJURIES, IS IT DIAGNOSTICALLY USEFUL TO PERFORM MRI IN PATIENTS WITH SUSPECTED PELVIC TRAUMA WITH STABLE VITAL SIGNS?

Recommendation
MRI can be considered in hemodynamically stable trauma patients with suspected spinal cord injuries (2B).

Evidence review or evidence summary
Spinal injuries are common (with reported rates of 13–30%) in multiple trauma patients [79-82]. Until spinal injuries are ruled out, the cervical vertebrae should be fixed, movement should be limited, and manual in-line stabilization should be maintained. However, this not only impedes various procedures or operations, but also has a number of side effects, including airway aspiration, bedsores, and an increased prevalence of pneumonia. For these reasons, spinal injuries should be excluded as soon as possible [83,84]. MRI for spinal injuries is the best option to diagnose damage to the spinal cord and soft tissue around the spine. However, the sensitivity of vertebral fracture diagnosis by MRI (12% according to one study) is much lower than that of CT [85]. The sensitivity of simple radiographs for vertebral fractures is also reported to be around 32–75%, which is much lower than that of CT, which has a sensitivity of 95–100% [86,87]. Therefore, CT is preferentially recommended as an initial examination for hemodynamically stable patients with suspected spinal injuries.

It has been reported that the delayed treatment of spinal cord injuries adversely affects the neurological prognosis and recovery [88-90]. Spinal cord injury can be suspected if neurological abnormalities are found and if there are signs of a fracture in the spine on a simple radiographic examination or CT. Therefore, it is recommended that MRI should be additionally performed for hemodynamically stable trauma patients with suspected spinal cord injuries.

Acceptability and applicability
The recommendations presented above are applicable and
acceptable.

REFERENCES


24. Edelen-Monroe BS, Browner BD, Jackson H. The role of stan-


47. Mata-Mbemba D, Mugikura S, Nakagawa A, Murata T, Kato Y, Tatewaki Y, et al. Canadian CT head rule and New Orleans...


