The role of radiological diagnostic methods in complicated combat chest trauma

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Abstract

Objective. To evaluate the effectiveness of radiation methods for diagnosing combat chest trauma at the stage of specialised surgical care.

Materials and methods. The results of diagnostic measures performed on 51 wounded with bilateral combat chest trauma were analysed. All the wounded underwent chest radiography (if necessary, in two projections). Ultrasound examination of the chest cavity was performed in real time. Spiral computed tomography was performed on multislice computed tomography scanners. Video thoracoscopy was performed in 20 (83.3%) of 24 wounded patients treated at the Department of Thoracoabdominal Surgery of the Zaitsev Institute of General and Emergency Surgery in 2022-2023. In 27 patients treated in the same department and the polytrauma department of the Kharkiv City Clinical Hospital of Emergency Medical Care named after Prof. O. I. Meshchaninov in 2014-2016, video thoracoscopy was not used as a diagnostic method.

Results. An important advantage of spiral computed tomography was that this method makes it possible to accurately determine the nature of damage to the chest cavity organs, the bone skeleton of the chest, post-traumatic complications and plan surgical treatment (correction) of existing injuries at the stage of providing specialised thoracic surgical care, in particular, using thoracoscopic access.

Conclusions. Combat chest trauma is a severe injury that should be considered within trauma protocols, where clinical signs are only informative in the early diagnostic stages for potentially fatal injuries.

Keywords: combat trauma; radiation diagnostic methods; chest; complications.

According to the literature, as a result of the armed conflict in Ukraine since 2014, the number of gunshot wounds to the chest has increased, now reaching 8–12% [1-3]. About 50% of those wounded in the chest die on the battlefield due to the development of haemorrhagic and painful shock, dysfunction of the thoracic and rib cage, acute emphysema and pulmonary atelectasis, haemo– or pneumothorax. The incidence of lung and heart contusion in gunshot wounds of the chest reaches 60–80% [1-3]. Erroneous diagnosis and treatment of gunshot wounds of the chest is noted in 30–35% of patients, the incidence of complications ranges from 13–21%, and mortality is up to 10% [1, 4–6].

Imaging of injuries is crucial in the diagnosis and treatment of chest trauma. While radiography is useful for initial treatment and triage, computed tomography (CT), as a more accurate method, helps to determine the severity of the injury and identify additional findings that may alter the course of treatment [7]. In addition, ultrasound (US) and CT are more informative in the case of post–traumatic and postoperative complications [7, 8].

Radiological examination is still the first to be performed in victims, as it makes it possible to detect life–threatening conditions such as tension pneumothorax, massive haemothorax, and iatrogenic injuries [9]. Focused Assessment with Sonography for Trauma (FAST) at the bedside in experienced hands helps to quickly visualise injuries and provide both initial medical care and in conditions where it is not possible to wait for a CT scan.

The American College of Surgeons’ classic Advanced Trauma Life Support (ATLS) protocol is vital for initiating resuscitation in some serious conditions. Clinical signs and symptoms are the cornerstone, but in many patients, rapid diagnostic methods are essential to make the right decisions [10].

This article focuses on the imaging of both blunt and penetrating airway and lung injuries, including the tracheobronchial tree, lung parenchyma, and those in the pleural cavity, as well as the diagnosis of postoperative and post–traumatic complications of combat chest trauma.

The aim of the study was to evaluate the effectiveness of radiation methods for diagnosing combat chest trauma at the stage of providing specialised surgical care.

Materials and methods

We have analysed the results of diagnostic measures performed on 51 wounded with bilateral combat chest trauma who were delivered to the stage of specialised surgical care. The wounded were divided into two groups. Group 1 included 24 wounded with bilateral combat chest injuries who were treated at the Department of Thoracoabdominal Surgery of the Zaitsev Institute of General and Emergency Surgery of the National Academy of Medical Sciences of Ukraine from 2022 to 2023, Group 2 – 27 wounded with bilateral combat chest injuries who were treated in the same department and the polytrauma department of the Kharkiv City Clinical Hospital of Emergency Medical Care named after Prof. O. I. Meshchaninov from 2014 to 2016.
Criteria for inclusion of wounded in the study: chest trauma as the most severe injury, which determines the severity of the victim's condition and the doctor's treatment and diagnostic tactics at the time of the study; bilateral chest wound; tension pneumothorax that cannot be eliminated by drainage of the pleural cavity; post-traumatic intrapleural and intrapulmonary complications lasting for 6–7 days; consent to the study (the victim read, understood and signed the informed consent form).

Criteria for exclusion of wounded from the study: irreversible stage of shock; unilateral chest injury; coma rated at 8 points or less on the Glasgow Coma Scale; damage to the heart and large vessels; impaired chest skeletonisation; refusal to participate in the study.

Men aged 18 to 49 years predominated among the wounded with bilateral chest injuries. These were practically healthy people before the injury. There were 19 (37.3%) victims aged 26 to 30 years. Forty-six (90.2%) of the victims had gunshot wounds to the chest: 22 (91.7%) in Group 1 and 24 (88.9%) in Group 2. Closed chest trauma was diagnosed in 5 (9.8%) of the wounded: in group 1 – in 2 (8.3%), in group 2 – in 3 (11.1%). Penetrating wounds were sustained by 35 (68.6%) victims: 16 (66.7%) in Group 1 and 19 (70.4%) in Group 2. Forty-three (84.3%) of the wounded had rib fractures: 20 (83.3%) in Group 1 and 23 (85.2%) in Group 2. The majority of bullet wounds were perforating. In 44 (86.3%) of the wounded, the chest trauma was of a combined nature. Only 7 (13.7%) of the wounded had isolated chest injuries. In 31 (60.8%) of the wounded, trauma to two anatomical areas was diagnosed with a leading injury to the chest. In 10 (41.7%) wounded of group 1 and 10 (37.0%) wounded of group 2, the injuries were thoracoabdominal in nature.

The ISS (Injury Severity Score) scale was used to assess the severity of the injury. In Group 1, 13 (54.2%) wounded were admitted in serious, extremely serious and critical condition; in Group 2, the injuries were thoracoabdominal in nature. The ISS (Injury Severity Score) scale was used to assess the severity of the injury. In Group 1, 13 (54.2%) wounded were admitted in serious, extremely serious and critical condition; in Group 2, the injuries were thoracoabdominal in nature. The ISS (Injury Severity Score) scale was used to assess the severity of the injury. In Group 1, 13 (54.2%) wounded were admitted in serious, extremely serious and critical condition; in Group 2, the injuries were thoracoabdominal in nature.

It should be noted that it was not possible to convincingly assess the extent and nature of intrapleural injuries in 23 (45.1%) wounded who underwent only pleural drainage at the stage of qualified surgical care. The nature of the chest cavity injuries in these wounded was finally assessed by CT scan at the stage of specialised surgical care.

The lung injuries were characterised according to the generally accepted international classification of organ injuries of the American Association for the Surgery of Trauma Committee – Abbreviated Injury Scale (AIS, 1991), assessing the size, depth and location of wounds, and the area of lung injury. All the victims had injuries to their intact lungs.

The examination of the wounded was carried out according to the following algorithm. The general condition of the wounded at the time of delivery, the nature of anatomical injuries, the amount of blood loss, complications from injuries, types of surgery, the course and complications of traumatic illness, the scope of additional examinations and repeated surgical interventions were assessed by studying extracts from medical records, records of doctors and specialists who performed various examinations, surgery protocols and anaesthetic manuals, and data from additional and instrumental research methods. During the history taking, the circumstances of the chest injury and its mechanisms, as well as the availability of personal protective equipment were ascertained. The general condition, state of consciousness, cardiovascular system, respiratory and digestive organs, genitourinary system, and skin were assessed. Blood pressure, pulse, and respiratory rate were measured. Particular attention was paid to the presence of wounds in the chest area, wound air suction, subcutaneous emphysema, signs of respiratory and cardiovascular failure. Clinical, biochemical and coagulation studies were performed in the dynamics.

All wounded in Groups 1 and 2 underwent chest radiography (in two projections, if necessary). Chest ultrasonography was performed in real time on SD 800 devices manufactured by Philips (Holland), using convex and linear transducers with a frequency of 3.5 MHz for general examinations and 7.5 MHz for superficial examinations. The purpose of dynamic ultrasound in the postoperative period was to assess the course of the posttraumatic and postoperative periods, to identify early and late complications of lung injury. In the postoperative period, the condition of the lung parenchyma was also assessed in the period from 1 to 30 days. In the event of complications (pleurisy, lung abscess), a puncture of the pleural cavity or abscess cavity was performed using ultrasound navigation.

Spiral computed tomography (SCT) was performed on multislice computed tomographs Emotion Duo (Siemens, Germany) and Aquilion 16 (Toshiba, Japan).

The reliability of radiation diagnostic methods was assessed according to generally accepted criteria: their sensitivity, specificity and accuracy. The sensitivity of the method was calculated as the ratio of the number of true positive results to the sum of the number of true positive and false positive results multiplied by 100; specificity – as the ratio of the number of true negative results to the sum of the number of true negative and false negative results multiplied by 100; precision – as the ratio of the sum of the number of true negative and false negative results to the sum of the number of false positive and false negative and true positive and true negative results, multiplied by 100.

Bronchoscopy was performed using Olympus BF-40 equipment (Japan), gastroduodenoscopy – using an Olympus GIF XQ-40 endoscope (Japan).

Videothoracoscopy was performed in 20 (83.3%) patients of group 1, while in group 2 this diagnostic method was not used. For video thoracoscopic operations, an endosurgical video complex consisting of equipment from Karl Storz (Germany) was used. The equipment included an endovideo camera, an insufflator (20 l/min), a xenon illuminator, an electrosurgical unit, an irrigation and aspiration system, a Sony 20 inch colour video monitor and a digital video recording device.

The data were statistically processed using STATISTICA 6 for Windows (USA).
Results

According to the results of X-ray examination performed on all wounded at the time of their admission to the hospital, heterogeneous opacification of the lung tissue, which was interpreted as bleeding along the wound channel, was detected in 34 (66.7%) wounded. In the course of time, according to the X-ray examination, the opacification of the lung tissue decreased in size and ceased to be detected in 23 (67.6%) of the wounded: by the 5th day – in 3 (8.8%), by the 10th day – in 19 (55.9%), by the 20th day – in 1 (2.9%).

In 10 (19.6%) patients, on days 1–10, a rounded shadow in the lung was noted against the background of heterogeneous darkening of the lung tissue, which was considered as an intrapulmonary haematoma. The dynamics of intrapulmonary haematoma was also determined on the basis of X-ray examination data within 10–24 days. Reduction and disappearance of the rounded shadow was noted in 8 patients, of whom in 5 of them it was clinically preceded by non–intense bleeding into the tracheobronchial tree (emptying of the intrapulmonary haematoma). An increase in the size and intensity of the rounded shadow, which was interpreted as an increase in intrapulmonary haematoma due to the resumption of bleeding into the lung parenchyma, was noted in 2 patients.

The appearance of a fluid level on the background of the rounded shadow was diagnosed in 2 (3.9%) of the wounded, which gave rise to the radiological conclusion of intrapulmonary haematoma suppuration. Changes in the size of the rounded shadow and the simultaneous appearance of fluid content in the pleural cavity were clinically consistent with bleeding into the pleural cavity, the source of which was a lung wound.

A foreign body (bullet or fragment) was detected in 6 (11.8%) victims. In addition, in 11 (21.6%) of the victims, the presence of foreign bodies (fragments) in the soft tissues of the chest was noted after surgery.

Infiltrative changes in the lung tissue were diagnosed in 11 (21.6%) wounded within 1 to 20 days. Bilateral pneumonia was diagnosed radiographically on days 10–14 in 3 (5.9%) of the wounded, and pneumonia of a single lung on day 3 in a wounded man after pulmonectomy performed as part of qualified surgical care. The pneumonic infiltration resolved in 9 wounded. The appearance of a rounded shadow with a fluid level on the background of lung tissue infiltration was considered as an abscess (2 observations). In 1 patient, positive dynamics was noted – a decrease in the size of the rounded shadow after abscess puncture under ultrasound guidance.

Table 1. **Lung ultrasound findings upon delivery of wounded**

<table>
<thead>
<tr>
<th>Ultrasound signs</th>
<th>Overall.</th>
<th>1st (n=24)</th>
<th>2nd (n=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No pulmonary pathology was detected</td>
<td>10</td>
<td>16,7</td>
<td>22,2</td>
</tr>
<tr>
<td>Lung tissue compaction to a depth of from 1 to 8 cm</td>
<td>41</td>
<td>83,3</td>
<td>77,8</td>
</tr>
<tr>
<td>Hypoechoic masses on the background of lung tissue compaction</td>
<td>3</td>
<td>8,3</td>
<td>3,7</td>
</tr>
<tr>
<td>Heterogeneous hovering on the background of hypoechoic clusters</td>
<td>1</td>
<td>4,2</td>
<td>-</td>
</tr>
<tr>
<td>Restoration of lung tissue structure on the 7th to 17th day</td>
<td>30</td>
<td>54,2</td>
<td>63,0</td>
</tr>
</tbody>
</table>

Table 2. **Ultrasound data of pleural cavities**

<table>
<thead>
<tr>
<th>Ultrasound signs</th>
<th>Overall.</th>
<th>1st (n=24)</th>
<th>2nd (n=27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No pathology of the pleural cavity was detected</td>
<td>10</td>
<td>16,7</td>
<td>22,2</td>
</tr>
<tr>
<td>The presence of up to 2 cm of fluid content in the pleural sinus</td>
<td>23</td>
<td>45,8</td>
<td>44,4</td>
</tr>
<tr>
<td>Presence of 2-7 cm of fluid content in the pleural sinus</td>
<td>4</td>
<td>8,3</td>
<td>7,4</td>
</tr>
<tr>
<td>Separate fluid accumulation in the pleural cavity</td>
<td>6</td>
<td>16,7</td>
<td>7,4</td>
</tr>
<tr>
<td>Presence of fluid accumulation in both pleural cavities</td>
<td>2</td>
<td>4,2</td>
<td>3,7</td>
</tr>
<tr>
<td>The presence of fluid accumulation in the pericardium</td>
<td>1</td>
<td>4,2</td>
<td>-</td>
</tr>
<tr>
<td>Presence of an empyema cavity</td>
<td>9</td>
<td>20,8</td>
<td>14,8</td>
</tr>
</tbody>
</table>
According to the X–ray examination, emphysema of the soft tissues of the chest wall persisted in 3 (5.9%) wounded for up to 18 days, and mediastinal emphysema in 1 (1.9%) wounded for up to 7 days. In 1 (1.9%) casualty, signs of pneumothorax persisted for 5 days.

The accumulation of free fluid of various volumes in the pleural cavity, detected in the period from 1 to 20 days after surgery in 28 (54.9%) patients, allowed us to suspect the presence of intrapleural bleeding and inflammatory reaction of the pleura with the accumulation of exudate.

Contrast examination (istulography) revealed a drained cavity in the pleura and mediastinum in 7 (13.7%) patients, which clinically corresponded to the formation of pleural empyma and fistula.

The sensitivity of the radiological method for detecting fluid was 51.4%, and intrapulmonary changes – 88.2%.

Ultrasound scanning of the lung tissue and pleural cavities was performed in all patients. This method was used as a routine to monitor the dynamics of the inflammatory wound process in the pleural cavities under the influence of treatment (Tables 1, 2).

When assessing the condition of the lung parenchyma, 41 (80.4%) of the wounded showed compaction of the lung tissue to a different depth (from 1 to 8 cm) in the area of the wound channel. During the dynamic examination, 3 (5.9%) of the wounded had hypoechoic clusters against the background of intense lung tissue compaction, which corresponded to the radiological detection of a rounded shadow in the lung wound. In 2 (3.9%) patients, heterogeneous suspension was detected in the lung tissue against the background of hypoechoic structures. They underwent puncture and drainage of the intrapulmonary fluid formation (abscess cavity). In all observations, purulent contents were obtained during puncture.

In 29 (56.9%) of the wounded, the assessment of the lung parenchyma in the dynamics showed the restoration of the lung tissue structure with the appearance of hyperechogenic single air inclusions and linear zones (the effect of “air bronchogram”) within 7 to 17 days of the formation of intrapulmonary hematoma or lung abscess.

During dynamic examinations within 3 to 16 days, the presence of free fluid in the pleural cavity with separation of the pleural sheets up to 2 cm at the level of the sinus was detected in 23 (45.1%) patients, with separation of the pleural sheets from 2 to 7 cm at the level of the sinus or the angle of the scapula in 4 (7.8%) patients; delimited fluid accumulation – in 6 (11.8%). Bilateral hydrothorax was detected in 2 (3.9%) of the wounded.

Ultrasound signs of pleural empyema (presence of different sizes and configurations of cavities with thickened compacted pleural sheets and heterogeneous content of reduced echogenicity with small hyperechoic inclusions) were noted in 9 (17.6%) patients.

The ultrasound method showed effectiveness in assessing the condition of the lung tissue and detecting its compaction to different depths (81.5%), early detection of such complications as intrapulmonary haematoma, accompanied by the presence of fluid content against the background of lung tissue compaction (19.2%), as well as fluid accumulation in the pleural cavities (81.8%) and pericardium (4.2%) with an assessment of its nature and amount. The sensitivity of the ultrasound method for detecting fluid in the thoracic cavity in the postoperative period was 95.1%, intrapulmonary complications – 92.2%, and the overall reliability of the results – 90.3%.

Chest CT was performed on arrival at the stage of specialised surgical care for 44 (86.3%) wounded: 24 (100%) in group 1 and 20 (74.1%) in group 2.

According to the results of the examinations (Table 3), all 44 wounded were found to have bone damage, lung tissue and post–traumatic changes; the presence, amount and nature of fluid; air in the pleural cavities; foreign bodies and their exact location.

A skin defect and soft tissue haematoma were detected in 38 (86.4%) of the wounded, and rib crossing in 22 (50%). Chest wall emphysema was diagnosed in 29 (65.9%) of the victims. Fluid (blood) was found in the pleural cavity in 28 (63.6%) of the wounded, and air in 22 (50%). An intrapulmonary haematoma was detected in 8 (18.2%) victims; a wound channel in the lung was traced in 6 (13.6%) victims.

The presence of fluid content in the pericardial cavity was detected in 1 (2.3%) wounded.

Since the study area of chest CT includes the upper abdomen, data on intra–abdominal injuries were obtained in 2 (4.5%) patients.

The sensitivity of the method for detecting free gas and fluid in the pleural cavities was 100%, and for pulmonary changes – 92.9%.

An important advantage of the CCT method was both the precise nature of the damage to the chest cavity organs, the bone skeleton of the chest, and post–traumatic complications, and the possibility of planning surgical treatment (correction) of existing injuries at the stage of providing specialised thoracic surgical care, in particular, using thoracoscopic access.

To monitor the dynamics of the wound process, 67 SCTs were performed: 36 in group 1 and 31 in group 2. The sensitivity of SCT of the chest cavity was 97.1%, specificity – 98.1%, and overall reliability of the results – 98.6%.

Discussion

Soft tissue injuries and rib fractures occur most often in mild chest trauma [11], which is usually uncomplicated but can be a threatening condition in victims with comorbidities, as rib fractures are associated with increased mortality due to pulmonary complications [11, 12].

Chest X–ray findings in blunt trauma can demonstrate pneumothorax, haemothorax, pulmonary contusion, bone fractures and evidence of aortic injury, proving its clinical utility. However, it should be borne in mind that many injuries detected on CT are not visualised on X–ray, and 20% of these injuries may influence the decision on further treatment. The initial assessment of the patient’s condition on a chest
radiograph is aimed at detecting life-threatening conditions such as tension pneumothorax, massive haemothorax, cardiac tamponade, floating rib fractures, or airway rupture [12, 13].

In penetrating trauma, if a chest CT scan is planned, there is usually no need for an exploratory radiograph, but it is recommended even in stable patients as it may detect subdiaphragmatic air, foreign bodies/fragments, pneumothorax or haemothorax. A chest X-ray is performed to detect subcutaneous emphysema or hyperinfected lungs from chronic lung disease.

Ultrasound has a limited and heterogeneous sensitivity (42 – 100%) [14], so further imaging studies or invasive interventions such as pleural puncture or videothoracoscopy are appropriate in stable patients. Ultrasound is more informative in blunt trauma than in penetrating trauma, so negative findings in a patient with penetrating trauma should be taken with caution. According to the ATLS guidelines, the FAST protocol is usually performed to assess circulation and haemorrhage on initial examination [10].

Identification of free fluid in the pericardial, intrathoracic or intra-abdominal spaces by hypo- or anechoic means, and the presence of a pneumothorax are the main goals of FAST [15]. It is contraindicated only in victims requiring immediate evacuation while they remain in the emergency department to clarify the diagnosis [18]. FAST is performed in unstable (primary) and stable (secondary) patients with chest wall trauma to detect life-threatening conditions, mainly cardiac tamponade and intra-abdominal bleeding, as well as massive haemothorax and pneumothorax (extended FAST protocol).

As FAST is not always performed by trained professionals in the emergency department, it plays only an initial screening role in the management of chest trauma and does not avoid the need for further investigations in stable patients (chest CT), but has the potential to diagnose internal bleeding when immediate surgery is required if the patient is unstable.

Ultrasound has a potential advantage over radiography as distinguishing subcutaneous emphysema or hyperinfected lungs from chronic lung disease.

Table 3. CT scan data on detection of pathological changes in chest wounds

<table>
<thead>
<tr>
<th>CT signs</th>
<th>Group</th>
<th>Overall.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st (n=24)</td>
<td>2nd (n=20)</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Skin defect and soft tissue haematoma</td>
<td>22</td>
<td>91,7</td>
</tr>
<tr>
<td>Intersection of edges</td>
<td>18</td>
<td>75,0</td>
</tr>
<tr>
<td>Presence of multiple foci in soft tissues with signs of gas density</td>
<td>19</td>
<td>79,2</td>
</tr>
<tr>
<td>(chest wall emphysema)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of contents in the pleural cavity with signs of gas density</td>
<td>20</td>
<td>83,3</td>
</tr>
<tr>
<td>(pneumothorax)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of contents in the pleural cavity with signs of fluid density</td>
<td>13</td>
<td>54,2</td>
</tr>
<tr>
<td>(haemothorax)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of a rounded area in the lung with signs of soft tissue density</td>
<td>5</td>
<td>20,8</td>
</tr>
<tr>
<td>(intrapulmonary haematoma)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of an irregularly shaped area in the lung with clear contours</td>
<td>2</td>
<td>8,3</td>
</tr>
<tr>
<td>(haemorrhagic saturation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collapsed lung</td>
<td>2</td>
<td>8,3</td>
</tr>
<tr>
<td>Presence of contents with signs of fluid density in the pericardial</td>
<td>1</td>
<td>4,2</td>
</tr>
<tr>
<td>cavity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity of the structure of the mediastinal fibre due to</td>
<td>3</td>
<td>12,5</td>
</tr>
<tr>
<td>multiple inclusions of gas cavities (mediastinal emphysema)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thoracic trauma is a severe injury and should be managed within trauma protocols where clinical signs are only informative in the early diagnostic stages for potentially fatal injuries. Radiological imaging modalities are useful and reliable for the classification of injuries in life-threatening gunshot wounds, moderate and mild chest trauma. Chest X-ray and ultrasound (FAST and extended FAST protocol) are affordable, rapid and non-invasive methods for the early diagnosis of life-threatening conditions such as tension pneumothorax, massive haemothorax or pericardial tamponade that require urgent action or immediate surgery. A chest CT scan is mandatory for moderate combat injuries in which intrathoracic or intra-abdominal secondary lesions can be expected. This method also provides additional information on delayed treatment of injuries. Performing these tests quickly can save the lives of the wounded and determine the final outcome of treatment.

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**References**


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