Thoracic Active Bleeding: Significance of Contrast Material Extravasation Demonstrated on Computed Tomography

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Contrast material extravasation (CME) is a well-documented radiological sign of active bleeding. The purpose of this study is to retrospectively investigate thoracic CME and its relations with surgical intervention and outcome.

Searching the database of the radiology information system (RIS) between 1998 and 2009, we identified 34 patients with CT images of thoracic CME. The CT and medical records were reviewed for the location of CME, cause of CME, time from arrival to CT, time from CT to intervention, time from arrival to intervention, systolic blood pressure, heart rate, international normalized ratio (INR), platelet count, arterial blood gas analysis, the mode of intervention, and final outcome.

Thoracic CME was more frequent in men than in women (n = 26 vs. n = 8) and in trauma patients than in non-trauma patients (n = 25 vs. n = 9). The number of patients requiring surgical intervention was greater than that of those not requiring intervention (n = 23 vs. n = 11). The active bleeder was identified intraoperatively in all cases (100%) underwent surgery. A significant relation was noted between traumatic causes of thoracic hemorrhage and 3 variables—younger age (p < 0.001), lower systolic blood pressure (p = 0.007), prolonged prothrombin time (higher INR) (p < 0.001). Prolonged INR and lower platelet count were more significantly associated with CME into the thoracic cavity than with CME into the mediastinum (p = 0.005). Blood acidosis was significantly associated with mortality (p = 0.005). Despite emergent surgical intervention the mortality rate was still high, at 34.8%.

This study verified CME on chest CT is a sign of thoracic hemorrhage, irrespective of the cause, trauma or non-trauma, is an indicator for the need of surgical intervention, especially in cases of CME into the thoracic cavity. The mortality can still be high in patients with acidosis despite early intervention.

Massive thoracic hemorrhage may compromise both ventilation and circulation and is an important cause of morbidity and mortality. Prompt identification of active hemorrhage in the chest is essential to determine the appropriate treatment measures and achieve favorable patient outcomes. The risk for death from thoracic hemorrhage increases linearly with total volume of chest hemorrhage [1]. Thoracotomy is indicated when the total 24-hour chest-tube output exceeds 1500 mL or when blood loss is >200 mL/hour for 3 consecutive hours, regardless of the cause of thoracic hemorrhage [2].

Because radiography is not sensitive to identify significant thoracic hemorrhage, computed tomography (CT) is frequently performed [3]. Contrast material extravasation (CME) on CT image is a clear sign of active bleeding from disrupted vascular...
structures. The clinical introduction of helical CT in 1991 has resulted in a dramatic improvement in the image quality of CT scans. This rapid imaging technique has also resulted in the development of new applications including CT angiography, which facilitates the evaluation of patients with vascular disease. The highly advanced multidetector helical CT allows simultaneous acquisition of data from multiple channels over a helical path, within a short period; for example, the entire chest can be scanned in < 20 seconds. In addition, the use of extremely thin slices and the minimization of motion artifacts facilitate high-quality three-dimensional reconstruction; these features are particularly beneficial when axial images are inconclusive. CT angiography (CTA) is frequently used for the diagnosis of patients with suspected blunt aortic injuries. Most researchers advocate that radioimaging and clinical signs positive for or suggestive of an aortic injury (e.g., mediastinal hematoma) be confirmed by performing CTA to enable the precise identification of the location and extent of the injury [4-7].

Thus, we can expect that the application of these advanced techniques can enable the accurate detection of hemorrhagic sites and facilitate treatment planning. It can also be used to guide angiographic or surgical intervention [8, 9].

For the reasons explained above, chest CT scan is increasingly being performed as a routine diagnostic procedure in apparently stable patients with vascular injuries. Although a growing number of studies support the utility of contrast-enhanced CT for the detection of acute hemorrhage, most of these studies focus on CME in the abdomen and pelvis [10-13]; few studies have investigated the utility of CT in thoracic hemorrhage.

The purpose of this study therefore is to retrospectively investigate the demography, clinical parameters, causes, treatments, and outcome of patients with thoracic CME.

MATERIALS AND METHODS

Institutional review board approval

Our institutional review board approved the retrospective examination of the chest CT and medical records. Informed consent was not required because the study was retrospective.

Research design

We searched the database of the radiology information system (RIS) maintained by our institution, for records entered between 1998 and 2009. We identified 34 patients (26 men and 8 women; age range, 10–91 years; mean age, 42 years) who underwent contrast-enhanced chest CT for chest trauma or acute chest pain and whose images showed thoracic CME. The medical records of these patients were reviewed and following items were recorded: demography, causes of CME, time from arrival to CT, time from CT to intervention, and time from arrival to intervention, systolic blood pressure, heart rate, international normalized ratio (INR), platelet count, arterial blood gas analysis, the mode of intervention, and final outcome.

CT protocol

All the CT images had been obtained using either a 4- or 16-channel MDCT scanner (LightSpeed; GE Healthcare, Milwaukee, WI, USA, and Somatom Sensation 16; Siemens Medical Solutions, Erlangen, Germany, respectively). The entire thorax was examined during chest CT, and the scanning was extended to the pubic symphysis if the abdominal architecture was required to be examined. A total volume of nonionic iodinated contrast material (Iohexol; Omnipaque 350, Amersham Health, Co. Cork or Ireland, GE Healthcare) injected intravenously was 100 mL, at the rate of 2 mL/sec. Images were obtained 60–70 seconds after the contrast material was injected. Images were reconstructed with the multiplanar reformations in the sagittal and coronal planes.

CT interpretation

All CT images were reviewed for the presence of thoracic CME by a junior radiologist and a senior radiologist who had 2 years and 15 years of experience, respectively, in emergency radiology. The CT images were considered positive for signs of active hemorrhage if they showed a jet of extravasated contrast material (Fig. 1a) or an irregularly outlined area of contrast pooling surrounded by hematoma in the proximity of the great vessels of the thorax (Fig. 1b). They were blinded to the results of other diagnostic tests and clinical outcomes. The data was recorded after a consensus was reached. The location of active bleeder was classified as cavity region, if the location of CME was in pleura, chest wall or lung parenchyma. In contrast to cavity region, the CME in mediastinal space or periaortic area was classified as mediastinal region CME.
Statistical analysis

The data was analyzed by χ2 test and Fisher exact test to determine the relation of gender, cause of thoracic hemorrhage, location of thoracic CME, history of subsequent surgical intervention, and clinical outcome on a 2 × 2 contingency table. The student t test was used to test the relations between the clinical parameters (age, time from arrival to CT, time from CT to intervention and time from arrival to intervention, systolic blood pressure, heart rate, INR, platelet count, power of hydrogen (pH) and partial pressure of oxygen (PaO2) in arterial blood gas analysis) with causes of thoracic CME, location of CME and clinical outcome. A two-tailed p value of <0.05 was considered statistically significant.

RESULTS

All of our study population had only a single site of CME. Thoracic CME was more frequent in men than in women (n = 26 vs. n = 8) and in trauma patients than in nontrauma patients (n = 25 vs. n = 9). The most common mechanism of chest trauma was motor vehicle accident, which accounted for 60% (15/25) of the trauma cases; fall and penetrating injury were other causative mechanisms in this patient group. On the other hand, aortic dissection was the cause of thoracic hemorrhage in 55% (5/9) of the nontrauma patients; other causes of hemorrhage in this patient group were lung abscess, esophageal cancer, and neurofibromatosis.

The number of patients requiring surgical intervention was greater than that of those not requiring intervention (n = 23 vs. n = 11). None received other modes of intervention, such as embolization or endovascular stent graft. The active bleeder was identified intraoperatively in all of these cases (100%). The surgical procedures included exploratory thoracotomy, primary repair or resection of lung parenchyma, pneumonolysis of the pleura for bleeding into the thoracic cavity, and excision of the injured vessel with stent-graft repair.

As compared with non-traumatic cause of thoracic CME, significant relation was noted between traumatic causes of thoracic CME and 3 variables (Table 2)—younger age (33.32 ± 21.51 years vs. 66.89 ± 16.90 years, p < 0.001), lower systolic blood pressure (81.54 ± 40.57 mmHg vs. 137.75 ± 42.71 mmHg, p = 0.007), prolonged prothrombin time with higher INR (1.67 ± 0.62 vs. 1.08 ± 0.12, p < 0.001). A lower platelet count and acidosis tended to occur more frequently in trauma patients than in nontrauma patients; however, the intergroup differences with respect to these variables did not reach statistical significance.

Higher INR (1.74 ± 0.63 vs. 1.18 ± 0.33, p = 0.005) and lower platelet count (129.58 ± 77.27 103/μL vs. 216.00 ± 80.10 103/μL, p = 0.004) (Table 2) were more significantly related with CME into the thoracic cavity than with CME into the mediastinum.

**Figure 1.** a. The contrast-enhanced CT image showed a jet of extravasated contrast material (white arrow) in the mediastinum. b. The contrast-enhanced CT image showed an irregularly outlined area of contrast pooling (black arrow) surrounded by hematoma in the proximity of the great vessels of the thorax.
Patients in non-intervention group and surgical intervention group did not differ in gender, causes (trauma or non-trauma), and CME location (cavity or mediastinum). The mortality rate in non-intervention group was higher than surgical intervention group, but did not reach statistical significance (63.6% vs. 34.8%, p = 0.151) (Table 1). Univariate analysis showed that mortality was associated with acidosis (pH: 7.11 vs. pH: 7.33, p=0.005) (Table 3). Among patients who received surgical intervention, mortality was significantly related to a shorter time interval from CT to intervention (91 vs. 358 min, p = 0.017). This indicated that patients with serious thoracic CME, mortality was unavoidable despite emergent intervention.

**DISCUSSION**

We found that CT can help detect thoracic hemorrhage in both trauma and non-trauma patients. Thoracic CME detected on CT were useful in accurate identification of active bleeders, which were confirmed by surgical exploration. The significance of CME to the diagnosis of thoracic hemorrhage is comparable to that of CME in the evaluation of hemorrhages in the abdomen and pelvis.

Young age, low systolic blood pressure, prolonged prothrombin time (high INR) were significantly associated with traumatic causes of thoracic hemorrhage. The annual incidence rate of motor...
vehicle accidents is higher in young adults than in elderly [14]. Trauma patients are prone to massive blood loss resulting in hypotension and coagulopathy, and the detection of the origin of active bleeders by CT would prove to be immensely beneficial to these patients. In many hospitals, plain radiography is increasingly being replaced by whole-body CT for the evaluation of patients with severe trauma; the cost-effectiveness of the use of whole-body CT in such patients is still under evaluation [15].

On comparing the patients with CME in the thoracic cavity and those with CME in mediastinum, we found that the prothrombin time was significantly longer and the platelet count significantly lower in the former group. This difference can be attributed to the fact that the tamponade effect of hemorrhage into the thoracic cavity is less efficient in stopping bleeding and predisposes the patient to massive

Table 3. Comparison of Clinical Parameter between Dead and Alive.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dead (n = 15)</th>
<th>Alive (n = 19)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time 1 (ER-CT) (min)</td>
<td>146.20 ± 190.68</td>
<td>120.16 ± 169.98</td>
<td>0.682</td>
</tr>
<tr>
<td>Time 2 (CT-OR) (min)</td>
<td>91.14 ± 57.88</td>
<td>357.71 ± 361.98</td>
<td>0.017*</td>
</tr>
<tr>
<td>Time 3 (ER-OR) (min)</td>
<td>205.29 ± 124.58</td>
<td>479.86 ± 470.41</td>
<td>0.057</td>
</tr>
<tr>
<td>Systolic pressure (mmHg)</td>
<td>85.21 ± 61.20</td>
<td>103.67 ± 32.73</td>
<td>0.321</td>
</tr>
<tr>
<td>INR</td>
<td>1.76 ± 0.75</td>
<td>1.37 ± 0.45</td>
<td>0.156</td>
</tr>
<tr>
<td>Platelet (1000/µL)</td>
<td>171.79 ± 83.95</td>
<td>162.16 ± 93.90</td>
<td>0.759</td>
</tr>
<tr>
<td>pH</td>
<td>7.11 ± 0.21</td>
<td>7.33 ± 0.09</td>
<td>0.005*</td>
</tr>
<tr>
<td>PaO2 (mmHg)</td>
<td>105.95 ± 126.36</td>
<td>130.13 ± 83.36</td>
<td>0.569</td>
</tr>
</tbody>
</table>

Abbreviation: INR: international normalized ratio; pH: acidity in arterial blood gas analysis; PaO2: partial pressure of oxygen in arterial blood gas analysis; Time 1 (ER-CT): time interval from presentation in emergency department to computed tomography room; Time 2 (CT-OR): time interval from computed tomography room to operation room; Time 3 (ER-OR): time interval from presentation in emergency department to operation room.

* Significance of correlation between two variables, p < 0.05.
blood loss. Acute blood loss and transfusion of blood supplements may induce dilutional coagulopathy [16]. On the other hand, hemorrhage into mediastinum areas tends to be localized and blood clotting may arrest the active bleeder temporarily, thereby reducing the requirement of blood transfusion [17].

Massive hemorrhage in the thoracic cavity leads to impaired ventilation and decreased preload and can perpetrate hemocolagulation disorders. These changes, in turn, decrease the chance of the survival of the patient [18]. Several causes can lead to coagulopathy in patients with thoracic hemorrhage. It may result from overwhelming activation of tissue factor, excessive consumption of circulating coagulation proteins, massive amounts of transfusion, metabolic alterations, hypothermia, or a combination of any of these factors. Development of coagulopathy has a significant impact on the morbidity and mortality of the patient with trauma [19].

The prevalence of CME in thoracic injury has not yet been established. Because this study is retrospective, we could not evaluate the sensitivity and specificity of CME in all patients.

In our study, more than half of these patients (67.6%, 23/34) underwent immediate surgical intervention, especially in the presence of CME into the thoracic cavity. The survival rate of patients who underwent surgical intervention was higher than that of those who did not undergo surgical intervention; however, this difference in the survival rate was not significant statistically.

Thoracic CME on CT scan is usually associated with a high overall mortality rate (44.1%, 15/34). The only factor independently associated with mortality was acidosis. Further acidosis might be a consequence of persistent hemorrhage and may be a component of a vicious cycle, including hypothermia, acidosis, and coagulopathy. Damage control intervention at the appropriate time can break this vicious cycle and enhance the chances of patient survival. This could be due to the small sample size in this study and the fact that we could not stratify the patients into groups with different levels of severity. Among patients who underwent surgical intervention, a shorter time interval from CT to intervention did not guarantee a better outcome. These findings reflected the severity of thoracic CME and the importance of rapid judgment and even more timely surgical intervention to save life.

According to the results of our study, we postulate a flow chart (Fig. 2) for assisting clinical decision making. When a radiologist found thoracic CME on CT scan, the thoracic cavity location of CME, coagulopathy and acidosis could help to alert clinicians about the severity of thoracic hemorrhage and the potential of death if not immediately intervened.

Our study was limited by the small sample size, retrospective design, and inclusion of only CME-positive cases, which could have resulted in the reduced statistical significance of our findings. However, the findings of this study clearly show that CT examination is a useful tool for the detection of thoracic active bleeding in both trauma and non-trauma patients. Further investigation is required to establish fully the predictive value of CT and the cost implications of performing CT routinely for all cases of suspected thoracic hemorrhage.

CONCLUSIONS

This study verified CME on chest CT is a sign of thoracic hemorrhage, irrespective of the cause, trauma or non-trauma, is an indicator for the need of surgical intervention, especially in cases of CME into the thoracic cavity. The mortality can still be high in patients with acidosis despite early intervention.

REFERENCES

胸腔活動性出血：在電腦斷層上對比劑外漏為表現的重要性

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對比劑外漏代表急性出血是一個已被證實的影像學徵兆。本回顧性研究的目的是驗證在胸部對比劑外漏的病人上手術治療和存活結果之間的相關性。

搜尋放射科報告系統（RIS）1998年至2009年的資料庫中，我們發現34例電腦斷層影像顯示胸部對比劑外漏。回顧病歷並記載以下項目：對比劑外漏的原因，從進入急診室到電腦斷層檢查的時間，從電腦斷層檢查到介入治療的時間，從進入急診室到介入治療的時間，收縮期血壓，心跳速率，凝血酶原時間國際標準化比值（INR），血小板數，動脈血氣體分析，介入治療模式，以及最終存活結果。

胸部對比劑外漏出現在男性比女性多（n = 26 vs. n = 8），在創傷患者比非創傷患者多（n = 25 vs. n = 9），病患需要手術治療多於不需要介入治療者（n = 23 vs. n = 11）。所有接受手術治療的病患在術中皆能找到對應於電腦斷層的出血點。外傷性出血比非外傷者年齡輕（p < 0.001），收縮壓低（p = 0.007）和凝血酶原時間延長（p < 0.001）有顯著相關。胸腔內出血比縱隔腔出血的凝血酶原時間延長和血小板數低有顯著相關（p = 0.005）。出現酸中毒與死亡率有顯著相關性（p = 0.005）。即使緊急手術介入治療後死亡率仍然很高，為34.8%。

本研究驗證了胸部電腦斷層上出現對比劑外漏是胸腔出血的徵兆。不論是外傷或非外傷性都是一個需要介入性治療的指標，即使緊急手術介入治療，出現酸中毒後死亡率仍然很高。