Pulmonary Contusion in Severe Head Trauma Patients*

Impact on Gas Exchange and Outcome

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Study objective: To evaluate the impact on morbidity and mortality of pulmonary contusion in multiple-trauma patients with severe head trauma.

Design: Matched-paired, case-control study

Setting: ICU at a tertiary university hospital.

Patients: During a 3-year period, 313 consecutive multiple-trauma patients with severe head trauma (Glasgow coma scale [GCS], ≤ 8) who were admitted to the ICU.

Interventions: Case-control matching criteria were as follows: (1) age difference within 5 years; (2) sex; (3) GCS in two categories; (4) similar pattern of injury; and (5) simplified acute physiology score II in five categories. A pulmonary contusion, defined by the clinical context and the result of a chest CT scan, was diagnosed in 90 patients. Analysis was performed on 90 pairs who were matched with 100% success.

Results: Ninety patients (29%) presented a diagnosis of pulmonary contusion. The presence of pulmonary contusion had an impact on the PaO₂/fraction of inspired oxygen (FIO₂) ratio, which was significantly reduced in patients with a pulmonary contusion. The ICU stay, the occurrence of complications such as nosocomial pneumonia or ARDS, the Glasgow outcome scale, and the mortality rate did not significantly differ between case patients and control subjects. Mortality also was not affected when patients were stratified according to the severity of the PaO₂/FIO₂ ratio.

Conclusion: In the study patients, pulmonary contusion alters gas exchange but does not appear to increase the morbidity and mortality of multiple-trauma patients with head trauma. A sample-size effect may limit the interpretation of the study. (CHEST 2003; 124:2261–2266)

Key words: head trauma; ICU; pulmonary contusion

Abbreviations: FIO₂ = fraction of inspired oxygen; GCS = Glasgow coma scale; GOS = Glasgow outcome scale; ICP = intracranial pressure; ISS = injury severity score; SAPS = simplified acute physiology score; SDD = selective digestive decontamination

Head trauma is the leading cause of death in young adults in the Western world. Several authors1–5 have demonstrated that cerebral hypoxia correlates with unfavorable outcome. Cerebral hypoxia constitutes a secondary insult that could be related to extracranial injuries, particularly chest trauma.3–8 Indeed, chest trauma can cause an acute respiratory failure that aggravates head trauma. The association of head and chest trauma has been described as a vicious circle leading to the constitution of secondary insult. Knowledge of the outcome determinants is interesting because it makes it possible to provide early accurate information to patients’ next of kin and to allow better allocation of ICU resources.

Chest CT scanning is systematically performed in many trauma centers in comatose multiple-trauma patients.9 Performing a chest CT scan makes it possible to make an easy diagnosis of pulmonary contusion. This injury has been involved in 40% of trauma patients.10 Pulmonary contusion can gener-
ate a worsening of gas exchanges, which may persist despite adequate management of patients. Despite advances in pulmonary care and ventilator management, pulmonary contusion has been described as contributing to higher mortality and morbidity for patients with other severe injuries, particularly in children. However, some data from analyses of the determinants of outcome in head trauma patients have not been in agreement with the previous assertion. For example, we previously described the absence of impact of a ventilator-associated pneumonia on the mortality of these patients. A study found that in patients with severe head injury, outcomes were not dependent on the presence of extracranial lesions. The objective of the present study was to determine the impact of pulmonary contusion, as diagnosed by CT scan, on the morbidity and mortality of mechanically ventilated patients with severe head trauma.

**Patients and Methods**

**Study Population and Study Design**

Nord University Hospital is a 700-bed teaching hospital. The ICU has 16 beds. A matched cohort study was conducted in our ICU over a 3-year period. Patients were selected according to the following criteria: head trauma with Glasgow coma scale (GCS) score of ≤ 8. The data of all patients admitted to the ICU during the study period were collected prospectively. Analysis was performed by matching head trauma patients with pulmonary contusion to similar head trauma patients without pulmonary contusion. Since this study was an observational and descriptive study on head trauma and pulmonary contusion, institutional review board approval was not required, in accordance with institutional review board regulations. Age, sex, simplified acute physiology score (SAPS) II, GCS, and injury severity score (ISS) were recorded at baseline. The following dates were recorded: admission and discharge from the ICU; and admission and discharge from the hospital. Hospital length of stay and mortality rate at the time of discharge from hospital were calculated. Outcome was determined by the Glasgow outcome scale (GOS) score, which was obtained when the patient was discharged from the hospital. The scale was defined as follows: 1, mild or no disability; 2, moderate disability; 3, severe disability; 4, vegetative state; and 5, death. Stratification was performed in order to distinguish patients with good recovery (ie, patients with no disease or those with mild or moderate disability), and those with bad recovery (ie, patients with severe disability and those in a vegetative state).

Adverse events including pneumonia, as defined elsewhere, and ARDS were recorded. All patients (case patients and control subjects) received selective digestive decontamination (SDD), as described elsewhere. SDD agents consisted of polymyxin E, gentamicin, and amphotericin B. A 2% mixture of these drugs was applied four times daily on the buccal mucosa, and a suspension of the same drugs was administered in the digestive tract at 6-h intervals. Systemic cefazolin therapy (1 g, three times daily) was administered to all SDD patients during the first 3 days. SDD medication was started on the day of hospital admission and continued until the patients were weaned from mechanical ventilation.

Sucralfate was not used systematically in patients to prevent upper digestive hemorrhage, but all patients received early enteral nutrition. All head trauma patients received mechanical ventilation with the ventilator set in the volume-controlled mode. Heat and moisture exchanger bacterial filters (Gibeck, Inc; Stockholm, Sweden) were inserted between the endotracheal tube and the ventilator circuit. Patients were positioned in the semi-recumbent position (ie, with head lifted 30°).

Head trauma patients were monitored as recommended by the guidelines. Patients with a GCS score of ≤ 8 and an abnormal brain CT scan finding had an intraparenchymal or intraventricular monitoring system of intracranial pressure (ICP) inserted (Camino; San Diego, CA). When persistent for ≥ 10 min, and in the absence of noxious stimulations, an increase in ICP of > 25 mm Hg, or a decrease in cerebral perfusion pressure of < 60 mm Hg were managed in a stepwise approach, as follows: (1) hemodynamic stabilization; (2) elevation of the head to a maximum of 30°; (3) sedation with analgesic medication; (4) artificial ventilation with controlled hyperventilation (ie, PaCO₂ 30 to 35 mm Hg); (5) osmotic therapy with mannitol (ie, 0.25 to 1 g/kg administered IV) or 23.4% saline solution (ie, 30 mL administered IV over 20 min); and (6) the administration of barbiturate (ie, thiopenthal) until burst suppression EEG. Transcranial Doppler ultrasonography for the evaluation of middle cerebral artery flow velocities was performed in patients with ICP increases.

A body CT scan was performed in all multiple-trauma patients admitted in the ICU, including cerebral, cervical, thoracic and abdominal examination. An IV injection of iodicine contrast material was administered in order to perform the chest CT scan.

**Identification of Case Patients**

Considerable confusion remains in the literature as to the correct nomenclature for pulmonary contusion. We selected the diagnosis of pulmonary contusion in all patients when all the following criteria were fulfilled: (1) history of blunt chest trauma; and (2) pulmonary contusion according to the appearance of four types of lesions on CT scans (ie, air-filled cavity or air fluid level in an intraparenchymal cavity; air-containing cavity or intraparenchymal air fluid level within the paravertebral lung; small peripheral cavity or peripheral linear radiolucency contiguous to a fractured rib; and a wedge-shaped shadow of a pneumonia or pulmonary contusion). The analysis of tissue density made it possible to isolate airspace filling by blood.

**Identification of Control Patients**

Each case patient with pulmonary contusion was matched to one control patient. Control patients were selected from among the patients admitted to the ICU for head trauma during the study period using a scoring system designed to match case patients with control patients having similar patterns of injury and comorbidity, except for pulmonary contusion. The criteria used in our matching procedure were based on variables considered to be important determinants of length of stay and mortality. Each case patient was matched to one control on the basis of the following three variables: (1) age ≥ 5 years; (2) sex; (3) GCS (two categories); (4) similar pattern of injury; (5) SAPS II (five categories).

**Statistical Analysis**

Statistical calculations were performed using a statistical software package (SAS, version 5; SAS Institute; Cary, NC). The χ²
test was used to compare categoric variables. One-way analysis of variance or Wilcoxon signed-rank test was performed to compare demographic characteristics. For the statistical analysis of the matched cohort study, two-way analysis of variance was used to examine the differences in length of hospital stay. Continuous variables were compared using Student t test for normally distributed variables, and Wilcoxon rank sum test was used for non-normally distributed variables. Overall mortality was compared using the McNemar statistic. The Mantel-Haenszel \( \chi^2 \) statistic was calculated for the stratified analysis of mortality. In order to isolate the patients in whom the impact of the pulmonary contusion was clinically significant, a stratification was performed according to Pa\(_2\)/fraction of inspired oxygen (Fi\(_{O_2}\)) ratio. For survival analysis, the odds ratio with 95% confidence interval were determined. For all statistical tests used, a \( p \) value of < 0.05 was considered to be statistically significant.

**RESULTS**

During the study period, 313 patients were admitted to the ICU for severe head injury with a GCS score of \( \leq 8 \). Among them, a pulmonary contusion was diagnosed in 90 patients (29%). Using our matching procedure, we found suitable matches for all of the head trauma patients who had pulmonary contusions (ie, case patients). The baseline characteristics of patients with pulmonary contusion and their matched head trauma patients in whom pulmonary contusion was not diagnosed (ie, control patients) were similar. Overall, successful matching was achieved in 100% of the variables used for matching. The two groups of patients (ie, case and control) were comparable for age, sex, and GCS. Pairs were not matched according to ISS. There was a significant difference in the ISS between the two groups because of the presence of the pulmonary contusion in the case patients. ICP was monitored in 21 case patients and in 29 control patients (\( p = 0.18 \)). The data extracted from cerebral CT scans did not differ significantly between the two groups. The results are shown in Table 1.

**Table 1—Characteristics of Study Population**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Case Patients</th>
<th>Control Patients</th>
<th>( p ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>33 ± 16</td>
<td>33 ± 17</td>
<td>0.80</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>79</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>GCS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–5</td>
<td>53</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>6–8</td>
<td>37</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>SAPS II</td>
<td>54 ± 18</td>
<td>52 ± 19</td>
<td>0.51</td>
</tr>
<tr>
<td>ISS</td>
<td>43 ± 7</td>
<td>32 ± 8</td>
<td>0.000</td>
</tr>
<tr>
<td>ICP monitoring</td>
<td>21</td>
<td>29</td>
<td>0.18</td>
</tr>
<tr>
<td>CT scan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle line shift</td>
<td>21</td>
<td>22</td>
<td>0.86</td>
</tr>
<tr>
<td>Absence of basal cisterns</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

*Values given as mean ± SD or No., unless otherwise indicated.

**Table 2—Respiratory Data on Admission to ICU**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Case Patients</th>
<th>Control Patients</th>
<th>( p ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pa(<em>2)/Fi(</em>{O_2}) ratio</td>
<td>281 ± 80</td>
<td>363 ± 75</td>
<td>0.006</td>
</tr>
<tr>
<td>PaCO(_2), mm Hg</td>
<td>40 ± 5</td>
<td>36 ± 4</td>
<td>0.02</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>28</td>
<td>6</td>
<td>0.0003</td>
</tr>
<tr>
<td>Hemothorax</td>
<td>13</td>
<td>8</td>
<td>0.25</td>
</tr>
<tr>
<td>Chest tube inserted</td>
<td>18</td>
<td>7</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Values given as mean ± SD or No., unless otherwise indicated.

**Respiratory Data**

Pulmonary contusion had a significant impact on gas exchange. Significant differences were found concerning the Pa\(_2\)/Fi\(_{O_2}\) ratio (\( p = 0.002 \)) and the measurement of PaCO\(_2\) (\( p = 0.02 \)). The number of cases of pneumothorax was significantly higher among head trauma patients with pulmonary contusion (\( p = 0.0003 \)). The number of cases of hemothorax did not differ significantly (\( p = 0.25 \)). The results are shown in Table 2.

**Morbidity**

The occurrence of pneumonia and ARDS was prospectively collected. No significant difference was observed with regard to the number of cases of pneumonia (\( p = 0.17 \)) and ARDS (\( p = 0.5 \)). The length of time between ICU admission and the occurrence of such complications did not differ significantly between case patients and control patients. Results are shown in Table 3.

**Outcome**

The length of hospital stay was similar between case patients and control patients (14 ± 10 vs 12 ± 11 days, respectively; \( p = 0.75 \)). Assessment of the recovery was performed by dividing patients in good recovery (ie, GOS 1 and 2) and poor recovery (ie, GOS 3 and 4). No difference in recovery was observed between the two groups of patients (\( p = 0.18 \)). The overall mortality rate was of 41% in case patients and 34% in control patients (odds ratio, 1.269; 95% confidence interval, 0.692 to 2.925;
p = 0.44) [Table 4]. After stratification using the \( \text{PaO}_2/\text{FiO}_2 \) ratio in case patients, the outcome of patients with a \( \text{PaO}_2/\text{FiO}_2 \) ratio of \( \leq 250 \) was similar to that of patients with a \( \text{PaO}_2/\text{FiO}_2 \) ratio of > 250 (Fig 1).

**DISCUSSION**

Head trauma patients in whom pulmonary contusion was diagnosed were compared with matched control patients (ie, head trauma patients without pulmonary contusion) in order to evaluate the attributable morbidity and mortality of pulmonary contusion in severely injured head trauma patients. We found the following: (1) pulmonary contusion occurred with an overall frequency rate of 29% in head trauma patients, (2) pulmonary contusion had a negative impact on gas exchange, and (3) hospital mortality did not seem to be influenced by the presence of pulmonary contusion, even after stratification according to the severity of the \( \text{PaO}_2/\text{FiO}_2 \) ratio.

The matching-pair method generates a more accurate estimate of the influence of pulmonary contusion on mortality than the unmatched method. Our approach involved matching patients with and without pulmonary contusion with respect to important prognostic factors, then determining the potential incremental mortality. The choice of a matched control study was dictated by the necessity to control potential confounding factors that are strongly correlated with the outcome. When case patients were compared with control patients, there were no significant differences in age, SAPS II, sex, and GCS scores. ISS was different because of the addition of pulmonary contusion to the head trauma. In addition, more pneumothoraces and hemothoraces were observed in case patients than in control patients, which emphasized the difference between the two groups in terms of ISS.

However, the design of the present study would have required > 2,000 patients to conclude with a power of 90% that the presence of a pulmonary contusion increased by 10% the mortality of head trauma patients. In our opinion, such a study cannot be performed in a single institution. The mortality was actually 19% higher in the pulmonary contusion group than in the control group, and while this difference was not statistically significant this may be due to the small sample size. Indeed, with a sample size five times that of the current study (ie, 450 patients in each group) this difference would be significant.

These results may be surprising because of the concept of systemic secondary insults. This concept is that chest trauma causes respiratory failure with hypoxemia and hypercapnia, aggravating the consequences of head trauma. A study performed in children with head injuries showed a worsening of outcome in the presence of pulmonary contusion. This study was not pair-matched, and the GCS of children with a pulmonary contusion was reduced when compared to the GCS of children without a pulmonary contusion. In our study, the pulmonary contusion had a moderate impact on gas exchange, and few patients had a \( \text{PaO}_2/\text{FiO}_2 \) ratio of < 250. In fact, CT scanning is extremely sensitive in detecting pulmonary contusions. Its use in diagnosing pulmonary contusion might result in the inclusion of patients with only minor degrees of lung disease. The subgroup analysis of the patients with a \( \text{PaO}_2/\text{FiO}_2 \) ratio of < 250 showed that no excess of morbidity and mortality was observed either. This subgroup analysis should be interpreted cautiously because of the small number of patients. The extension of pulmonary contusion within the first 24 h has been correlated with death and morbidity. Measurement of contusion volume has been described as a determinant of patients with a high risk of complications, particularly ARDS. However, a previous study found that the extent of contusion assessed on hospital admission chest roentgenograms was not predictive of mortality. The volume of pulmonary contusion was not estimated in the present study, and patients were stratified according to \( \text{PaO}_2/\text{FiO}_2 \) ratio to provide a better reflection of contusion severity. Even after stratification, no difference in mortality was observed between the two groups. However, the objective of the present study was not to assess the effects of hypoxemia on the outcome of head trauma patients. Because of the emergent role of CT scanning in the management of multiple-trauma patients, the diagnosis of pulmonary contusion is more and more common. Our goal was to evaluate the clinical relevance of such a diagnosis.

Moreover, the diagnosis of a pneumothorax or hemothorax is obvious on a CT scan. Occult pneumothoraces, which are defined as anterior pneumothoraces observed only on CT scans, and small-volume hemothoraces (ie, those < 200 mL)
were treated by a conservative approach (ie, without insertion of a chest tube). The patients in whom a conservative approach is pursued have been carefully observed, with chest radiographs repeated at 6 and 12 h. The development of clinical distress led to the immediate insertion of a chest tube. This attitude explains the fact that there were 55 hemothoraces or pneumothoraces, yet only 25 chest tubes were inserted.

The importance of head injury as an outcome determinant was previously highlighted in a study comparing 36 “isolated” severe head injury patients and 44 severe head injury patients with associated extracranial injuries. The occurrence of secondary insults was comparable between the two groups. The conclusion was that the presence of extracranial injuries did not affect the outcome. In a previous pair-matched study, we have shown that the presence of ventilator-associated pneumonia had no impact on the mortality of severe head trauma patients. These results confirm that head injury is the first determinant of mortality in these multiple-trauma patients. Pulmonary contusion has been identified as a risk factor of ARDS occurrence. A tendency in favor of this statement was observed in the present study since six cases of ARDS were observed among the case patients compared with three cases among the control patients. The absence of a significant result likely was related to the small number of patients developing ARDS. The relationship between pulmonary contusion and pneumonia is not obvious in the literature. In the present study, the number of patients with pneumonia among case patients and control patients was not significantly different. The mechanism that leads to pneumonia in head trauma patients could explain this result. Patients with head injury experience compromised local-airway immune defense mechanisms very early in their illness. This allows microorganisms to adhere and persist at mucosal surfaces. Impaired levels of consciousness would additionally favor continuous aspiration and the subsequent development of pneumonia. The majority of cases of ventilator-associated pneumonia among head trauma patients are related to these local conditions. The presence of a pulmonary contusion is probably a nonessential event in severely injured head trauma patients. The results of the above-cited pediatric study are in agreement with our results. Pneumonia occurred in 17% of children with pulmonary contusions, compared with 30% of those without pulmonary contusions. The difference was not statistically significant, and no link between pneumonia and contusion was highlighted.

To our knowledge, the present study has assessed for the first time the effect of pulmonary contusion on the outcome of adult head trauma patients. Pulmonary contusions diagnosed on CT scans and a history of trauma have a negative impact on gas exchange but not on hospital mortality. However, the low power of this study may limit the relevance of the results.
REFERENCES