Utility of high-resolution chest CT scan in the emergency management of haemoptysis in the intensive care unit: severity, localization and aetiology

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ABSTRACT. The purpose of this study is to assess the utility of the chest high-resolution computed tomography (HRCT) scan for estimating the severity of haemoptysis, localize the bleeding site and to determine a cause of the bleeding. We reviewed 80 consecutive patients who were admitted to a respiratory intensive care unit (RICU) for haemoptysis and who underwent unenhanced HRCT scanning and fibre-optic bronchoscopy (FOB) within 48 h. The number and type of lobar involvement on the CT scan were correlated to prognostic factors, the amount of bleeding and the bleeding aetiology. We compared HRCT scan observations on localization and bleeding aetiology with FOB results. The number of involved lobes was correlated with the daily (p<0.001) and cumulative (p<0.001) volume of haemoptysis and found to be significantly greater in the group of patients who were mechanically ventilated and/or died (2.7 vs 1.8, p<0.03). FOB and HRCT localized the bleeding site or side, respectively, in 71 (89%) and 64 (80%) patients (p>0.05). Of the nine patients without FOB localization, HRCT localized the bleeding site in six patients (67%). The initial HRCT scan correctly identified 48 aetiologies (60%), whereas FOB identified only 2 proximal bronchogenic carcinomas. The extent of lobar involvement seen by HRCT is a prognostic factor correlated with the daily and cumulative volume of haemoptysis. FOB and HRCT are complementary techniques for bleeding site localization. HRCT-scan is also the best exam to determine the cause of haemoptysis, even while it is occurring.

Materials and methods

We reviewed clinical charts, fibre-optic bronchoscopy (FOB) results and radiographic findings in 80 consecutive patients with haemoptysis admitted to respiratory intensive care unit (RICU) in a 2-year period. All patients underwent chest radiography, unenhanced HRCT scanning and FOB within 48 h. The FOB was performed on patients at bedside. The HRCT parameters were sequential 1 mm thin section images at 10 mm intervals.

The amount of bleeding was estimated using the following scale. Haemoptysis was classified as mild (50–200 ml in 24 h), moderate (200–400 ml), or massive or severe (more than 400 ml in 24 h or requiring mechanical ventilation). The cumulative volume was estimated as the amount of bleeding that occurred before the HRCT scan. The side (right/left) and site (lobe) of the bleeding were assessed by a combination of chest radiography, FOB and HRCT.

HRCT scan interpretation

Bleeding intensity and severity

The HRCT analysis was performed blinded to the clinical history. The severity of haemoptysis was
evaluated by the number of lobes involved on the HRCT scan and by the bilateral or unilateral abnormalities related to bleeding. Each lobe was counted as one; the left upper lobe was divided into culmen and lingual, and each of these parts was considered as a lobe. The totality of the lobe or one segment of one lobe was counted as one lobe’s involvement. These data were correlated with prognostic factors and evolution: the daily haemoptysis volume, the cumulative volume and acute respiratory distress leading to mechanical ventilation and/or death.

**Bleeding site localization**

Localization by HRCT was defined as ground-glass opacities and/or alveolar consolidation; the latter abnormalities were considered to reflect the filling of the alveolar lumen with blood. In the absence of alveolar filling, isolated cavitation and/or a mass were considered to be localizing lesions. Interpretation of the HRCT findings must take into consideration possible redistribution of blood to dependent portions of the lung. For this reason, when ground glass opacities were present in both the upper and lower lobes, areas with more attenuation were considered the bleeding site and, in cases of homogeneous attenuation, the upper lobes were considered to be the bleeding site.

The bleeding site was defined by the combination of abnormalities on the HRCT scan (ground-glass opacities or alveolar consolidation, cavitation or mass) and localized active bleeding or a clot or bronchial lesion on FOB.

**Bleeding aetiology**

Bronchiectasis was diagnosed on an HRCT scan when it showed a bronchial diameter larger than the diameter of the neighbouring arteries. Large irregular opacities on HRCT scans were considered indicative of tumours. All tumours were histologically proven. Aspergilloma was diagnosed only when a typical fungus ball (a round mass of soft-tissue density with an air-crescent sign) was visible in HRCT images. Extensive areas of consolidation associated with focal cavitation surrounded by alveolar nodules were considered to indicate acute tuberculosis. Diagnosis of tuberculosis sequelae was based on a combination of the following findings: calcified granulomas; retracted linear opacities; bronchiectasis; and pleural thickening, mainly of the upper lobes and apical segment of the lower lobes. Bronchiectasis associated with sequelae of tuberculosis was classified as post-tuberculosis lesions, as opposed to isolated bronchiectasis.

The cause of bleeding was assessed on the basis of patient history, the physical examination, chest radiography, FOB, HRCT, microbiology, histology when available, and evolution. When no aetiology was found, a follow up HRCT was performed at 1–3 months. If there was no explanation for the haemoptysis, it was considered cryptogenic.

**Statistical analysis**

The percentages of cases in which the bleeding site was detected, and the underlying bleeding aetiology determined by FOB and by HRCT, were compared using the \( \chi^2 \) test, or Fisher’s exact test when the \( \chi^2 \) test could not be performed. For the severity analysis we used Mann-Whitney or Spearman tests to study the correlation between the number of lobes involved and the daily haemoptysis volume, the cumulative haemoptysis volume, bleeding aetiology and patients who received respiratory assistance or died.

**Results**

There were 23 female and 67 male patients, ranging in age from 28 years to 86 years (mean: 56 years). Haemoptysis was mild, moderate or massive in 35, 19, and 26 patients, respectively.

The number of lobes involved (0 to 6) was compared with the gravity of haemoptysis: mild, moderate, or massive. Results are detailed in Figure 1. In patients group with mild haemoptysis, 27 patients had fewer than 3 lobes involved (27/35). In patients group with moderate haemoptysis, 14 patients had fewer than 3 lobes involved (14/19). In patients group with massive haemoptysis, 10 patients had fewer than 3 lobes involved (10/26).

The number of lobes involved was correlated with the daily volume of haemoptysis (Spearman test; \( p<0.001 \)).

220 ml in 24 h vs >200 ml in 24 h (Mann-Whitney U-test: \( p=0.036 \)); <400 ml in 24 h vs >400 ml in 24 h (Mann-Whitney U-test: \( p=0.0024 \)). The number of lobes involved was also correlated with the cumulative volume of haemoptysis (Spearman test; \( p=0.001 \)).

Mechanical ventilation was given to seven patients. Two patients (2.5%) died of cardiogenic shock and cardiac arrest (bronchopulmonary cancer and bronchiectasis). The number of lobes involved was significantly greater in the group of patients who were mechanically ventilated and/or died: 2.7 versus 1.8 (Mann-Whitney U-test: \( p<0.03 \)). The severity was not significantly different compared with the bleeding aetiology (Mann-Whitney U-test: \( p=0.18 \)).

The relationship of the bleeding site detected by HRCT and/or FOB to the amount of haemoptysis is presented in Table 1. The bleeding site was identified in 71 (89%) and 64 (80%) patients, respectively, on FOB and HRCT-scan. FOB showed the involved lobe in 60 patients and only the involved side in 11 patients. HRCT showed the involved lobe in 58 patients and the involved side in 6 patients. The bleeding site was identified by chest radiography in 27 patients (33%). Chest radiography showed the involved lobe in 19 patients (23%), and only the side in 8 patients (10%). Among the 9 patients without FOB localization, HRCT localized the bleeding site in 6 patients (6/9 = 67%). Both examinations localized the bleeding site in 58 patients with side concordance in all patients and lobe concordance in 52 patients. In six patients, HRCT identified the lobar bleeding origin whereas FOB showed only the side of origin. In two patients, HRCT and FOB showed the origin on the same side, but in different lobes. In two cases of massive haemoptysis, bleeding localization by FOB was not possible, whereas it was accomplished by HRCT. Overall, there was no statistically significant difference in accuracy (\( p>0.3 \)) between HRCT and FOB in assigning
bleeding side and site, regardless of the amount of blood expectorated. However, the association of the two examinations localized the bleeding site in 77 patients (96%).

FOB identified the cause of bleeding in only two patients with proximal bronchogenic carcinoma. The initial HRCT scan correctly identified the cause of bleeding in 49 patients. Underlying pathologies identified (Table 2) included bronchiectasis (n=34) including tuberculosis sequelae (n=15/34), bronchopulmonary cancer (n=4), aspergilloma (n=4), active tuberculosis (n=4) and various other causes (n=2) (namely, pulmonary abscess and pneumonia). In one patient the haemoptysis cause was a pulmonary emboli diagnosed by CT pulmonary angiogram. A control HRCT scan in the following 3 months revealed four patients with bronchiectasis. 27 patients had no diagnosis despite extensive work-up, and were classified as having cryptogenic haemoptysis. Overall, cryptogenic haemoptysis, bronchiectasis and tuberculosis sequelae accounted for 81% of all aetiologies.

**Discussion**

Physicians in charge of patients with haemoptysis requiring RICU admission face a triple challenge: to assess the severity of the illness, to localize the bleeding and to find its cause.

**Bleeding severity**

Haemoptysis can terrify patients. Consequently, it is useful to have the more objective assessment afforded by the HRCT scan, especially if the patient’s capacity to cough decreases or the patient ingests blood, so that they underestimate its volume. The usual criteria used to identify patients with haemoptysis requiring intensive care are the haemoptysis volume and its consequences (need for mechanical ventilation [2], blood transfusions and haemodynamic support), and also the underlying disease and comorbidities, and the cardiovascular status and pulmonary reserve [3]. Our series demonstrates that the HRCT results can be related to the severity of bleeding. We evaluated the extent of lobar involvement as a severity factor. To our knowledge, this is the first study that describes severity factors in HRCT scans for haemoptysis. The number of lobes involved was correlated with the daily (p<0.001) and cumulative volume (p<0.001) of haemoptysis and was significantly greater in the group of patients who were mechanically ventilated and/or who died: 2.7 versus 1.8 (p<0.03). Our results suggest that CT scans may help physicians make treatment decisions, especially when a patient’s diminished coughing ability might lead to an underestimation of the amount of bleeding. We believe that there is probably one factor more important than the volume of expectorated blood in evaluating the severity of haemoptysis: the amount of blood that may be retained within the lungs without being brought up. The amount of expectorated blood does not always correlate with the actual volume of bleeding. HRCT could be another way to evaluate the amount of bleeding and its severity.

**Bleeding site localization**

We report the largest series comparing HRCT with FOB for bleeding site localization in the RICU. FOB and HRCT performed similarly in bleeding site localization.

<table>
<thead>
<tr>
<th>Amount of bleeding (ml in 24 h)</th>
<th>HRCT-scan +</th>
<th>HRCT-scan –</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;200</td>
<td>22</td>
<td>6</td>
<td>28 (38%)</td>
</tr>
<tr>
<td>200–400</td>
<td>16</td>
<td>3</td>
<td>19 (27%)</td>
</tr>
<tr>
<td>&gt;400</td>
<td>20</td>
<td>4</td>
<td>24 (34%)</td>
</tr>
</tbody>
</table>

Total 64 (80%) 16 (20%)

HRCT, high resolution CT; FOB, fibre-optic bronchoscopy.

Table 1. Bleeding site localization: comparison of HRCT and FOB results (no statistically significant difference). The association of the two exams localized the bleeding site in 77 patients (96%)
FOB and HRCT localized the bleeding site in 71 (89%) and 64 (80%) patients, respectively. In six of the nine patients without localization by FOB, the HRCT scan localized the bleeding (6/9 = 67%). Of the 16 patients without localization by HRCT, FOB localized the bleeding site in 13 patients (13/16 = 81%). Furthermore, in six patients, HRCT identified the lobar bleeding origin whereas FOB showed only the lung side of origin.

The accuracy of CT for bleeding site localization has seldom been reported in the literature [4, 5]. Alveolar filling of variable density is a known cause ofground-glass opacities, and consolidation on the CT scan is assumed to correspond to haemorrhage and is useful for localizing the bleeding site [6]. Haponik et al [7], in a retrospective study of 32 patients with haemoptysis, showed that CT correctly localized sources of bleeding in 23 of the 26 patients in whom a site was identified by FOB, but the overall impact on clinical management was small and does not support routine use of this imaging procedure in the evaluation of haemoptysis. Recent studies examining FOB and CT-scan utility in the initial evaluation of haemoptysis suggest that CT might be more helpful than FOB, and could even replace it, for localization of bleeding sites [4, 5, 8]. Hsiao et al [5] showed that FOB before bronchial artery embolisation is unnecessary in patients with haemoptysis of known causes if the bleeding site can be determined from the combination of chest radiography and/or CT scan, especially in patients who do not need the FOB for airway management. Revel et al [4] also suggested that CT could replace FOB as the first-line tool of investigation in patients with large to massive haemoptysis.

**Bleeding aetiology**

The superior ability of CT to detect the cause of bleeding in patients with haemoptysis, compared with FOB, has already been demonstrated [8, 9]. These authors suggest that FOB should only be performed after a CT scan when the CT scan is uninformative. The main advantage of the CT scan is that it allows an evaluation of the tissues surrounding the proximal and distal bronchi [8, 10]. In this study, HRCT scans showed the cause of bleeding in 48 patients (48/53; 90.5%); four cases of bronchiectasis were diagnosed at the HRCT-scan control, and one patient had pulmonary emboli diagnosed on helical-CT angiography. FOB revealed the cause of haemoptysis in only 2 patients (2/57; 4%; p < 0.0001). HRCT-scan successfully identified all lung tumours (n=4), whereas FOB failed to reveal 2 bronchopulmonary cancers (2/4; 50%). However, CT is of limited usefulness in detecting endobronchial tumours, especially in patients with haemoptysis, where blood clots may simulate endobronchial tumours [11]. There are relatively few data series in the area of intensive care. Primary and secondary bronchiectasis, lung cancer and mycetoma were the leading causes of haemoptysis in our cohort. Mal et al [3] identified tuberculosis, bronchiectasis and idiopathic haemoptysis as the most frequent causes of a retrospective French cohort of 56 patients with life-threatening haemoptysis.

**HRCT and/or FOB**

There is no consensus about the optimal investigational approach or management of major haemoptysis [12]. Removal of an unstable patient from the intensive care unit is unwise unless a therapeutic procedure is planned. Moreover, the most important advantage of FOB is its rapid availability and therapeutic role when haemoptysis is severe and the patient is not sufficiently stable to be immediately taken to the radiology department. Thus, in cases requiring immediate local vasoconstrictive treatment with current active bleeding, pre-treatment work-up may be limited to the clinical radiographic evaluation and FOB; a HRCT scan should be performed at a later time. For patients without current active bleeding, additional work-up must be organized according to available examination time and efficacy [13]. In this case, we believe that the HRCT scan and FOB provide complementary data regarding bleeding localization and aetiology, and that the HRCT scan could replace FOB in the immediate management of haemoptysis and that the HRCT scan can guide the FOB. We propose an algorithm including FOB and HRCT for the emergency management of haemoptysis (Figure 2).

Our study has several limitations, including its retrospective design. There is no gold standard for the precise localization of bleeding. The unique, definite, localized sign is iodine extravasation into the bronchus during bronchial angiography. We used the combination of FOB and HRCT results to determine the definite bleeding site. The current use of multidetector-row CT bronchial angiography to visualize the bronchial arteries and non-bronchial systemic arteries [14, 15] was not used in this study. Furthermore, the use of helical CT-angiography could detect pathology with pulmonary artery tropism [16] and greatly modified the ensuing endovascular treatment. However, vessel visualization was not an objective of our study.

In conclusion, this study suggests the possiblity of using the degree of lobar involvement (>3) on HRCT scan as a prognostic factor for haemoptysis. FOB and HRCT are complementary methods of bleeding-site localization; in cases without active bleeding, the HRCT scan could replace FOB in emergency situations. Nevertheless, in the unstable patient, and in patients with bilateral pulmonary pathologies where localization by HRCT remains difficult, FOB has a place. The HRCT scan is more accurate than FOB in determining the aetiology of haemoptysis, especially in patients with bronchiectasis and tuberculosis.
Figure 2. Haemoptysis management in the respiratory intensive care unit (RICU). Patients admitted to the RICU could be managed according to the presence of persistent active bleeding and the amount of bleeding during the previous 24 h. In case of persistent active bleeding, fiberoptic bronchoscopy (FOB) should be performed first to localize the bleeding site and to start a local treatment. In case of intermittent bleeding, a high-resolution computed tomography (HRCT) scan could be performed first to localize the site, assess severity and diagnose the cause of bleeding. In our institute, patients with bleeding of more than 200 ml per 24 h (independent of respiratory function) are guided to interventional radiology.

References

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