Critical Care Pearls: Management of Massive Hemoptysis

Definition of massive hemoptysis

• from 200 mL to 1000 mL/24 hrs
• >=600 mL in 24 hrs
• mortality ~7 to 30%
• death results from asphyxiation, rather than exsanguination
• clinical consequences such as degree of aspiration, airway obstruction or hypotension
Degree of bleeding

- measurement of the volume of hemoptysis can be unreliable
  - exaggerated by the patient
  - underrated because the volume of blood engulfing the involved lobes or lungs is not quantitated and may be significant
- the quantity of hemoptysis does not correlate with the seriousness of the etiology

Source of the bleeding

- nasopharynx
- upper GI tract
- bronchial arteries (90%) whereas the pulmonary arteries may be the cause in only 5%
- massive hemoptysis accounts for only 1-2% of all hemoptysis

Excluded
Major Hemoptysis in HK

- Retrospective review during 2000 – 2006
- 3006 admissions, involving 2260 patients
- 251 patients have LTH
- mainly due to tuberculosis (active or inactive) and bronchiectasis
- HK ~10% of hospital admission due to hemoptysis is life-threatening

Chan VL, Chu CM et al.
United Christian Hospital, Hong Kong,
Int J Tuberc Lung Dis. 2009 Sep;13(9):1167-73.

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**Table 1** Causes of life-threatening haemoptysis

<table>
<thead>
<tr>
<th>Pulmonary</th>
<th>Infections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronchietasis, including cystic fibrosis</td>
<td>Mycobacteria, especially tuberculosis</td>
</tr>
<tr>
<td>Emphysematous bullae</td>
<td>Fungal, including mycetoma</td>
</tr>
<tr>
<td>Tumour</td>
<td>Lung abscess</td>
</tr>
<tr>
<td>Bronchogenic carcinoma</td>
<td>Necrotizing pneumonia</td>
</tr>
<tr>
<td>Bronchial carcinoma</td>
<td>Pneumonia</td>
</tr>
<tr>
<td>Metastases</td>
<td>Trauma</td>
</tr>
<tr>
<td>Sarcoma</td>
<td>Blunt or penetrating chest injury</td>
</tr>
<tr>
<td>Vascular</td>
<td>Suction induced tracheal alcers</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>Pulmonary artery rupture</td>
</tr>
<tr>
<td>Arteriovenous malformations</td>
<td>Tracheostomy procedures</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>Bronchoscopy including biopsy</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>Vasculitis</td>
</tr>
<tr>
<td>Bronchial vascular abnormalities</td>
<td>Goodpasture’s syndrome¹</td>
</tr>
<tr>
<td>Mitral stenosis²</td>
<td>Wegener’s granulomatosis²</td>
</tr>
<tr>
<td>Left ventricular failure³</td>
<td>Systemic lupus erythematosus²</td>
</tr>
<tr>
<td>Haematological</td>
<td>Becher’s disease</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>Drugs or poisons</td>
</tr>
<tr>
<td>(congenital &amp; acquired)</td>
<td>Anticoagulants</td>
</tr>
<tr>
<td>Pulmonary disorders</td>
<td>Thrombolytic agents</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Penicillamine</td>
</tr>
<tr>
<td>Bronchial blush</td>
<td>Trimethadione</td>
</tr>
<tr>
<td>Endometriosis</td>
<td>Solvents</td>
</tr>
<tr>
<td>Foreign body</td>
<td>Crack cocaine</td>
</tr>
<tr>
<td>Lymphangioilematmosis</td>
<td></td>
</tr>
<tr>
<td>Idiopathic</td>
<td></td>
</tr>
</tbody>
</table>

¹More commonly manifest as alveolar rather than airway haemorrhage.
Investigation

- Sputum x G/S & C/ST
  - AFB smear & C/S
  - Cytology
- CBP, clotting profile
- Type & screen
- RFT, urinalysis
- Fungal serology
- Autoimmune markers
- Echo / TEE

CXR

- normal or non-localizing in 20%–45% of patients with hemoptysis
- cavitary lesions, infiltrates, atelectasis, or tumors
- A fine reticulonodular pattern can represent intra-alveolar bleeds or pneumonia
Life-threatening hemoptysis

Airway protection/Lung isolation
+ Identify bleeding source
  (CXR / CT / Bronchoscopy)
- correct coagulopathy
- antibiotics

Rigid bronchoscopy

Angiographic Embolisation

Surgery

Management

- resuscitation and protecting the airway
  - Volume resuscitation, blood transfusion & correct coagulopathy
- positioned with the bleeding side down
Lung Isolation

1. Bronchial intubation by ETT

Less practical in L-sided bleeding
2. Balloon tamponade

- Adult: 8 to 14 French tube
- Children: 3 to 5 French tube
- Larger catheters used to obstruct the larger, more proximal airways
For left-sided bleeding

- the trachea is intubated over the bronchoscope first with the patient in the left lateral position
- A size Fogarty catheter is passed through the vocal cords beside the endotracheal tube
- balloon is inflated in the left main bronchus

Endobronchial blockers

- balloon catheters
  - Fogarty, Foley or pulmonary artery catheters
  - Fogarty blockers with smaller balloon catheters (0.5 to 3 ml) allow segmental lung isolation
  - the Arndt wire-guided or Cohen flexitip blockers
Parallel Technique of Endobronchial Balloon Catheter Tamponade

Avoid using several previous methods
• to cut the cap
• to make a detachable cap
• to use a guide wire

Advantage:
• The suction channel is available during the procedure
Univent blockers

• single-lumen endotracheal tubes with an anterior channel that houses a balloon catheter
• the central lumen of the balloon catheter
  – allows suctioning
  – to give insufflate oxygen into the non-ventilated lung
• bronchial mucosal ischemia, bronchial rupture and pneumothorax are possible side effects because of generating high cuff pressures

Univent blocker advantages over the F.C

• displacement is less likely
• suctioning, pulmonary lavage, oxygen insufflation, and even high-frequency jet ventilation can be provided through the univent tube to the occluded lung.
• if conventional ventilation is desired, the blocker can be deflated and withdrawn without having to reintubate the patient
Problems of endobronchial blockers

- Tedious final placement after intubation
  - Especially when bronchoscopic visualisation is limited by massive hemoptysis
- Cannot be used when the side of the bleeding is unknown
- Dislodgement is more common than in double-lumen tubes
- By blocking up the pathological side, it is impossible to monitor continued bleeding or secretions

Balloon tamponade

- Potential risk of ischemic mucosal injury and postobstructive pneumonia
3. Double lumen endotracheal tube

Double Lumen ET tubes (DLT) (Carlens & Robertshaw)

- Most widely used means of achieving lung separation and one-lung ventilation.
- Several different types of DLT,
  - **Carlens** (with carinal hook), 1949
  - **Robertshaw** (without carinal hook)
    - Red Rubber
  - **Bronchocath** PVC (similar to Robertshaw)
Double Lumen ET tubes (Carlens) with Carinal Hook

- Left mainstem endobronchial intubation using a Carlens tube.
- A carinal “hook” used for correct positioning.

Double Lumen ET tubes (Robertshaw)

A. Left Robertshaw Tube
B. Placement at the Carina
C. Right Robertshaw Tube
D. Placement at the Carina
Double Lumen ET tubes (Robertshaw)

- Lt and Rt-sided forms without a carinal hook, (easier insertion)
- D-shaped, large-diameter lumina
  - Allow easy suctioning + low resistance to gas flow
  - Fixed curvature to facilitate proper positioning + reduce the possibility of kinking.
- Original Red rubber tubes three sizes: (S,M,L)
  - For our local population size S & M are used
  - S for Female, M for Males

Double Lumen ET tubes (Robertshaw PVC = Broncho-Cath)

- Disposable
- Sizes
  - French sizes 35, 37, 39, and 41.
  - Size 28 for pediatric cases.
- Design
  - The right-sided endobronchial tube is designed to minimize occlusion of the right upper lobe.
    - The right endobronchial cuff is doughnut shaped and allows the right upper lobe ventilation slot to ride over the right upper lobe orifice.
**DLT main features**

**2 Sides: Right & Left**

For right-sided DLT:
- additional ventilation slot at bronchial cuff
- for ventilating the RUL (because the right mainstem bronchus is too short to accommodate both the right lumen tip and a right bronchial cuff)

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**DLT main features (1)**

- two catheters are bonded together
  - 2 Curves: Oropharyngeal, bronchial;
  - 2 Lumens
    - Bronchial lumen is long enough to reach a mainstem bronchus.
    - Tracheal lumen ends with an opening in the trachea.
DLT main features

- 2 Cuffs: bronchial (1-3mls) & tracheal (20ml)
  - Lung separation is achieved by inflation of two cuffs, the proximal tracheal cuff and the distal bronchial cuff located in the mainstem bronchus.

Original Red rubber vs Clear, PVC (Bronchocath)

1. Reusable tubes
2. Less cost
3. Although the red rubber tubes may be more difficult to insert, they are less likely to dislocate during patient positioning and surgical manipulation.
4. Durable tracheal cuff rubs against the patient’s upper teeth if these teeth are prominent and sharp, as compared with the thicker-walled cuffs of the red rubber tubes.
5. Can withstand repeated sterilization.

1. Disposable
2. More Expensive
3. Easy to insert, positioning and to dislocate.
4. The thin-walled tracheal cuffs of the disposable tubes are much more likely to tear.
5. If Wrong size of tube is used (insertion is attempted) - tube cannot be reused because sterility is compromised.
**Original Red rubber vs Clear, PVC (Bronchocath)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>easy recognition of the blue colored endobronchial cuff when FOB is used.</td>
</tr>
<tr>
<td>6.</td>
<td>confirmation of position on CXR (radioopaque lines)</td>
</tr>
<tr>
<td>7.</td>
<td>Red/yellow color tube - gas exchange not visible.</td>
</tr>
<tr>
<td>8.</td>
<td>Foreign body reaction not suitable for long term used.</td>
</tr>
</tbody>
</table>

**Bronchocath is the choice nowadays**

*for lung separation and ILV in ICU setting*
Choices of DLT

• Left Sided – mostly used
  – Because of problems with proper positioning of Right-sided DLT in ensuring that Rt upper lobe is well ventilated (more difficult)

• Left Sided DLT contraindicated only if;
  – Left main bronchus stenosed, distorted or infiltrated by tumour.
Sizing

- Adequate functional lungs separation
- Establish optimum access for suctioning and bronchoscopy
- Prevent migration of the tube and consequent herniation of the bronchial cuff into the carina.
- Oversized tubes can cause excessive tracheobronchial trauma and are difficult to insert.

DLT sizes *(Broncho-Cath™)*

- Size ranges from 28-41 Fr.
  - Based on the patient’s height
- 37 Fr for women
- 39 Fr for men
- Patient height/Tube size/Depth of insertion
  - 136-164 cm / 37 Fr / 27 cm
  - 165-179 cm / 39 Fr / 29 cm
  - 180-194 cm / 41 Fr / 31 cm

Table 10.5  Recommendations for size and length of left double-lumen tube. (Adapted from Brodsky et al. 1991, 1996)

<table>
<thead>
<tr>
<th>Length of tube</th>
<th>Size of tube from measured tracheal width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Me: Females 170 cm tall: Insert tube to a depth of 29 cm</td>
<td></td>
</tr>
<tr>
<td>For every 10 cm increase in height, increase depth of insertion by 1 cm</td>
<td>Width of trachea (mm)</td>
</tr>
<tr>
<td>18</td>
<td>41</td>
</tr>
<tr>
<td>16</td>
<td>39</td>
</tr>
<tr>
<td>15</td>
<td>37</td>
</tr>
<tr>
<td>14</td>
<td>35</td>
</tr>
</tbody>
</table>

*The above lengths and sizes are not necessarily applicable to right-sided tubes.*
### Size of DLT

- **Too Small**
  - fail to provide adequate lung isolation
  - will require large endobronchial volume or pressure that could damage the bronchus

- **Too LARGE**
  - can rupture the trachea or bronchus

- **Minimal leaking technique**
  - the bronchial cuff should be inflated to the minimal volume that provide lung isolation

### Positioning of DLT

#### Steps for insertion

**A. Preliminary steps;**
- prepare and check tube
- lubricate tube
- Established patient monitors.
- Pre Oxygenate patient for 3 – 5 minutes
- Induce with I/v miadazolam /fentanyl/scoline

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### Table: Sizing polyethylene chloride double-lumen tubes (K3)

<table>
<thead>
<tr>
<th>Tube size (Fr)</th>
<th>Circumference (mm)</th>
<th>Common diameter (mm)</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>5F</td>
<td>9.0</td>
<td>5.0</td>
<td>Pediatric</td>
</tr>
<tr>
<td>7F</td>
<td>10.0</td>
<td>5.5</td>
<td>Small adults</td>
</tr>
<tr>
<td>8F</td>
<td>11.0</td>
<td>6.0</td>
<td>Medium adults, usual female size</td>
</tr>
<tr>
<td>11F</td>
<td>16.0</td>
<td>8.5</td>
<td>Large adults, usual male size</td>
</tr>
</tbody>
</table>
Positioning of DLT
Steps for insertion

B. Intubation;

1. Laryngoscopy is performed once pt is adequately anesthetized.
2. Insert tube with distal concave curvature tip facing anteriorly.
3. Remove stylet once through the vocal cords.
4. Rotate tube 90 degrees (in direction of desired lung).
5. Advancement of tube ceases when resistance is encountered. Average lip line is 29 ± 2 cm.

Positioning of DLT
Steps for insertion

B. Intubation;

6. If a carinal hook is present (Carlens DLT), must watch hook go through cords to avoid trauma to them. Insert tube with distal concave curvature facing anteriorly, and remove stylet once through the vocal cords. (As step 2 – 3)
7. Then in step 4, rotate 180 degrees (so distal concavity faces posteriorly and hook is anterior). Once hook is past cords, rotate so that distal concavity is pointed right or left as desired.
8. Connect to the breathing circuits.
Position confirmation

- Height may be poorly correlated with tracheobronchial dimensions \((r < 0.25)\)
- Chest X-rays
- Auscultation
  - following sequential clamping
  - result in incorrect positioning in \(\sim 40\%\) of cases
- Bronchoscopic confirmation

Placement checking by auscultation

1. **Inflate tracheal cuff** (high volume, low-pressure, capacity 20 mL max)- expect equal lung ventilation (same as regular ETT).
   - Both lungs should expands and BS should equal bilaterally. This indicates the DLT is in the trachea not in esophagus
   - If BBS not equal, probably too far down (tracheal lumen opening is at carina or even endobronchial). Withdrawal by 2-3 cm fixes this.

2. **Inflate bronchial cuff** and ventilate.
   - Both lungs should expand & BS should equal bilaterally
   - This indicate the bronchial cuff is not over inflated to such an extent to occlude the bronchial lumen.
Placement checking by Auscultation

3. Disconnect (remove the cap) the tracheal tube (Rt tube of Lt DLT) and clamp the right side
   • Only the left lung should expand
   • Listen to the disconnected tube to detect air leak

4. Disconnect (remove the cap) the bronchial tube (left tube in the Lt. Sided DLT) & Clamp the Left Side.
   • Only the right lung should expand.

Note: If lung isolation needs to be achieved urgently to prevent soiling of the unaffected lung (eg. Empyema or Bleeding into the lung) the Bronchial cuff should be inflated FIRST before the above steps are taken.

Placement checking of DLT

Cuff inflation and sequential clamp; by auscultation

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Breath Sounds Heard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamp Right Lumen Both Cuffs Inflated</td>
<td>Left</td>
</tr>
<tr>
<td>Clamp Left Lumen Both Cuffs Inflated</td>
<td>None or Very ll</td>
</tr>
<tr>
<td>Clamp Left Lumen Deflate Left Cuff</td>
<td>Left</td>
</tr>
</tbody>
</table>
1. Inflate tracheal cuff (high volume, low-pressure, capacity 20 mL max)- expect equal lung ventilation (same as regular ETT). If BBS not equal, probably too far down (tracheal lumen opening is at carina or even endobronchial). Withdrawal by 2-3 cm fixes this.

2. Clamp the right side (marked “tracheal” for left-sided tube) and remove cap from the right connector. Expect some left sided ventilation through bronchial lumen, and some air leak past bronchial cuff, which is not yet inflated.

3. Slowly inflate bronchial cuff until minimal or no leak is heard at uncapped right connector. Go slow – it only requires 1-3 cc of gas and bronchial rupture is a risk.

4. Remove the clamp and replace the cap on the right. Check that both lungs are ventilated. This ensures that the bronchial cuff is not partially or completely obstructing the contralateral hemithorax.

5. Selectively clamp each side, and expect visible chest movement and audible breath sounds only on the right when left is clamped, and vice versa.
DLT malposition

1. The bronchial lumen enters the wrong side
   Consequences:
   - wrong lung collapse,
   - inadequate separation,
   - increased PIP,
   - instability of the DLT,
   - tracheal or bronchial laceration,
   - obstruction of RUL bronchus by left-sided tube
     bronchial cuff.

2. Too far down
   - BS will not be heard on contralateral side since tracheal
     lumen may be endobronchial.

DLT malposition (cont)

3. Too shallow.
   - BS good bilateral through bronchial lumen, inaudible
     through tracheal lumen (inflated bronchial cuff
     obstructs gas flow through tracheal lumen).
   - Deflate cuff(s) and rotate/advance bronchial tube into
     desired side.

4. R sided tube may obstruct RUL bronchus.
DLT malposition (con’t 2)

5. LUL bronchus may occasionally be obstructed by L DLT bronchial cuff
6. Bronchial cuff herniation may obstruct ventilation on its own side, or herniate over the carina and obstruct contralateral ventilation
7. Rare complication is
   – Tracheal rupture
     ✷ use minimal-leak technique to inflate tracheal cuff
   – Bronchial rupture

Placement checking of Rt-DLT

Checking tube placement with fiberoptic bronchoscope
Placement checking of DLT
Checking tube placement with the fiberoptic bronchoscope

Figure 10.4  Left-sided double-lumen tube position. (After Altkenhead AR, Jones RM. Clinical Anaesthesia. Edinburgh: Churchill Livingstone; 1996, with permission.)

Tracheal lumen view:
Good placement
Tracheal lumen view: too proximal

Bronchial lumen view: good placement
Bronchial lumen view: too distal

After Position Checking & Confirmation by FOB

- Movement as small as 16 to 19 mm with left-sided tubes and 1 to 8 mm with right-sided tubes can cause malposition and inadequate ventilation
- Sedation
- The DLT is anchored and securely tapes.
- Recheck by means of auscultation and /or FOB after positioning patient laterally.
Fiberoptic bronchoscopy in DLC

- A standard 4.9-mm outside diameter bronchoscope will pass through the lumens of 39 and 41 French tubes with adequate lubrication and can be utilized to assess tube placement in most adult patients.
- A pediatric bronchoscope (3.6- to 4.2-mm outside diameter) is needed to pass through the lumens of 37 French tubes.

Complications of double-lumen tubes

- Malposition
- Traumatic laryngitis
- Tracheobronchial tree disruption especially overinflated bronchial cuff
ILV

- can be life saving in massive hemoptysis until definitive therapy like surgery, embolotherapy or interventional bronchoscopy can be instituted
- When the site of bleeding is unknown, double-lumen tubes should be used instead of endobronchial blockers

ILV

1. CPAP to each limb of the DLT with spontaneous ventilation
2. Differential ventilation and PEEP applied with a single ventilator and a flow divider
3. Independent ventilation with two synchronized ventilators
4. Ventilation with two independent asynchronous ventilators
5. A combination of different modalities
Synchronous ILV

- either one or two ventilator circuits
- identical respiratory rate of both lungs
- but, the respiratory cycle can either be in phase or 180 degrees out of phase.
- Selective PEEP can also be added to either lung
- tidal volumes and inspiratory flow rates are set independently
- Using two Servo 900 ventilators, a ‘master’ and a ‘slave’ ventilator are synchronised using an external cable.
- A one-ventilator system employs a Y-piece with separate PEEP valves, the airflow and tidal volume to each lung is then determined by the individual lung compliance and airway resistance.

Asynchronous ILV

- Using two ventilators
- greater flexibility, less complicated
- well tolerated
- no proven disadvantage compared to synchronized ILV
  - The potential for decreased venous return, increased PVR, & decreased CO exists when the lungs are being randomly ventilated, particularly when the two systems are out of phase.
  - Although PAP & PAWP were noted to be difficult to interpret, CO determinations and systemic pressures were stable when compared with values obtained before AILV.
  - Experimental study confirmed no significant difference in gas exchange or hemodynamic measurements when synchronous and AILV were compared in an animal model of acute ULD.
Localisation of bleeding site

Flexible fiberoptic bronchoscopy

- ETT >8mm ID
- Allow supporting oxygenation and ventilation while allowing passage of the bronchoscope through the ET tube
- to visualize the origin of bleeding
- to control bleeding

**PROS:**
- safe
- bedside procedure
- without GA
- can evaluate bleeding down to the fifth or sixth bronchial orifice
- to obtain specimens by biopsy, washing, and brushing to aid in bacteriologic, histologic, and cytologic evaluations

**CONS:**
- suctioning abilities inferior to the larger diameter rigid scope.
FOB: control bleeding

- endobronchial wedging technique
- endobronchial balloon tamponade
- topical instillation of vasoactive agents
  - epinephrine (1 : 20000 dilution)
  - iced saline lavage
  - Thrombin, thrombin-fibrinogen-thrombin, fibrin glue
- oxidized regenerated cellulose (surgicel) mesh
  - Chest 2005;127;2113-2118
- precision laser photocoagulation

Bronchoscopy-Guided Topical Hemostatic Tamponade Therapy
- Oxidized regenerated cellulose mesh

- in 57 patients (13 TB patients) with persistent endobronchial bleeding
- Immediate arrest of haemoptysis was obtained in 56 of 57 patients (98%)
- all remaining free of haemoptysis for the first 48h
- recurred in six patients (10.5%) between 3 and 6 days after the procedure
- postobstructive pneumonia developed in five patients
- the material used was absorbed in all of these patients without significant signs of visible foreign body reaction on follow-up bronchoscopy 4 weeks later

Chest 2005;127;2113-2118
Rigid Bronchoscopy

- larger diameter tube
- greater suctioning capability
- reliably maintains a patent airway
- commonly requires general anesthesia, although conscious sedation can be used.
- limited use in accessing the upper lobes or peripheral airways; therefore, sites of bleeding expected in these areas of the lungs are better evaluated with a flexible bronchoscope or angiographic technique.

Timing of bronchoscopy

- Controversial
- Early:
  - high rate to localise bleeding
- Delay (> 48hr after admission):
  - preferred in stable patients
Massive hemoptysis (N=80)

<table>
<thead>
<tr>
<th>Site of bleeding</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>CXR</td>
<td>46%</td>
</tr>
<tr>
<td>CT</td>
<td>70%</td>
</tr>
<tr>
<td>FOB</td>
<td>73%</td>
</tr>
</tbody>
</table>


Computed Tomography

- Except for life-threatening condition, CT should be performed before bronchoscopy
- ~5 - 30% remained non-diagnostic among patients with hemoptysis
FOB or CT

- Complimentary
- Stable: CT
- Unstable: bronchoscopy

FOB before BAE?

N= 28 patients,
- bleeding site determined through bronchoscopy was consistent with that determined through radiographs in 23 patients (82%)
- bronchoscopic findings were indeterminate in 7%
- May not be necessary if the aetiology of haemoptysis is known, the site of bleeding can be determined from radiographs, and no bronchoscopic airway management is needed

Angiography + embolisation

In stable patients, multiple imaging modalities (CXR, CT, bronchoscopy)
- to confirm the diagnosis
- to locate the bleeding site
- with a variable success rate of 17 to 93%.

In unstable patients, diagnostic angiography for localizing the bleeding site because it allows for immediate institution of treatment.

Indications for BAE

- Unresectable tumor
- postradiation-treated lung
- bilateral lung parenchymal diseases
- recurrent hemoptysis after surgery
- any other refractory massive hemoptysis
Steps of transcatheter embolization

1. Thoracic aortogram:
   - to visualize and localize all the main systemic arteries to the lung(s).
   - these arteries may be bronchial or nonbronchial/systemic. (including the bronchial arteries, internal thoracic artery, external thoracic artery, periscapular artery, cervical artery, intercostal artery, and inferior phrenic artery)

2. Once the feeding arteries are localized, selective bronchial arteriography is performed to characterize the bleeding vessels.

   Common characteristic:
   - (1) dilatation and tortuosity of the course of the peribleeding vessels,
   - (2) marked hypervascularity
   - (3) active contrast extravasation
3. An embolic is used polyvinyl alcohol (PVA) particles, Gelfoam and/or dextran microspheres.

4. Postembolization bronchial arteriogram and thoracic aortogram are performed to ensure a complete blockage of all the feeding arteries with no further bleeding from the vessels.

Studies on BAE

<table>
<thead>
<tr>
<th>Authors</th>
<th>N</th>
<th>Underlying Disease</th>
<th>Success Rate (%)</th>
<th>Recurrence Rate (%)</th>
<th>Embolic Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando et al</td>
<td>26</td>
<td>Various malignancy 35.5%</td>
<td>85</td>
<td>27</td>
<td>PVA, Gelfoam, or Hélix coils</td>
</tr>
<tr>
<td>Borhan et al</td>
<td>38</td>
<td>Cystic fibrosis</td>
<td>96</td>
<td>29</td>
<td>PVA</td>
</tr>
<tr>
<td>Bustamante et al</td>
<td>37</td>
<td>TB/Bronchiectasis</td>
<td>92</td>
<td>37</td>
<td>Microspheres</td>
</tr>
<tr>
<td>Cohen et al</td>
<td>20</td>
<td>Cystic fibrosis</td>
<td>95</td>
<td>40</td>
<td>PVA + Gelfoam</td>
</tr>
<tr>
<td>Corr</td>
<td>70</td>
<td>TB, PNA</td>
<td>90</td>
<td>13</td>
<td>Microspheres</td>
</tr>
<tr>
<td>Cremaschi et al</td>
<td>209</td>
<td>Various Bronchiectasis 46%</td>
<td>98</td>
<td>13</td>
<td>PVA + Gelfoam</td>
</tr>
<tr>
<td>Kato et al</td>
<td>101</td>
<td>Benign pulmonary diseases</td>
<td>94</td>
<td>32</td>
<td>PVA + Gelfoam</td>
</tr>
<tr>
<td>Møl et al</td>
<td>96</td>
<td>TB/Bronchiectasis</td>
<td>77</td>
<td>43</td>
<td>Gelfoam, microsphere, PVA, PVA, bupivacaine</td>
</tr>
<tr>
<td>Park et al</td>
<td>19</td>
<td>Malignancy</td>
<td>79</td>
<td>33</td>
<td>PVA</td>
</tr>
<tr>
<td>Ulfaker et al</td>
<td>33</td>
<td>TB</td>
<td>81.8</td>
<td>18</td>
<td>Gelfoam, Absolute ethanol</td>
</tr>
</tbody>
</table>

Control rates 77-95%
Recurrent rate 13-43%

Semin Respir Crit Care Med 2008;29:395–404
Recurrence

- immediate recurrence
  - often occurs due to incomplete embolisation
- later recurrence
  - collateralization or recanalization of either the feeding artery or new bleeding vessels

Recurrence after BAE in HK

N=251, UCH in HK

- immediate success rate of 95.7%
- 5-year recurrence rate of 45.0%
- Recurrent life-threatening haemoptysis was independently associated with
  1. past history of haemoptysis (P = 0.024)
  2. presence of broncho-pulmonary shunt (P = 0.013)
  3. incomplete embolisation (P = 0.002).

Int J Tuberc Lung Dis. 2009 Sep;13(9):1167-73.
Major haemoptysis in Hong Kong: aetiologies, angiographic findings and outcomes of bronchial artery embolisation.
Recurrence after BAE

Italy study, N=88, FU 8d-102m

- chronic lung disease, especially to pulmonary tuberculosis or mycetoma
- systemic-pulmonary shunts
- history of massive haemoptysis

Indicators predictive of success of embolisation: analysis of 88 patients with haemoptysis

Recurrence of hemoptysis in mycetoma

- BAE is usually unsuccessful
- Contributions from the non-bronchial systemic arterial system involved in abnormal vascular connections and cannot be targeted
- Collateral vascular channels from the pulmonary and systemic circulation may supply enough blood flow to the involved area in which haemoptysis often recurs;
- Re-embolization will not be successful.

- Patients with mycetoma were at risk of
  - technical failure of BAE (4/15; 27%)
  - early recurrence after BAE (7/25; 28%)

Complication of BAE

- immediate complication rate of less than 1%
- most frequently observed complications are postembolization syndrome (leukocytosis, fever, atelectasis, pleural effusion, or pleuritic pain)
- bronchial wall or esophageal wall necrosis
- embolization of nonfeeder/bleeding vessels
  - the coronary arteries, resulting in chest pain and ACS
  - spinal arteries causing spinal cord ischemia

Surgery
Surgery

• Until 3 decades ago, Rx of choice once bleeding site was localised.
• During acute life-threatening hemoptysis, there is a 20%–40% operative mortality (within 7 days of OT)
• Morbidity 25-50%

Surgery

Indication
• when BAE is unavailable
• bleeding is unlikely to be controlled by embolisation
• leaking aortic aneurysm,
• selected cases of arteriovenous malformations, hydatid cyst, iatrogenic pulmonary rupture, chest injuries, bronchial adenoma, or haemoptysis related to mycetoma resistant to other treatments
A patient with PA catheter

- Pulmonary artery rupture
  - May be temporarily controlled by withdrawing the catheter slightly
  - and reinflating the balloon to compress the bleeding vessel more proximally
  - surgical resection of the bleeding vessel is the definitive management

A patient with tracheostomy

- development of a tracheal-arterial fistula, usually the innominate artery
- prompt application of anterior and downward pressure on the tracheal cannula and overinflation of the tracheostomy balloon may help to tamponade the bleeding vessel
- immediate surgical review should be requested
- Deflation of the tracheostomy balloon and removal of the tracheal cannula should be performed in a controlled environment
Surgical Rx: not an option

(i) it is not therapeutic;
(ii) it is not feasible because of poor lung function or bilateral pulmonary diseases or inoperable carcinoma
(iii) patients decline surgery
(iv) patients of other comorbidities


<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57.9 ± 14.1</td>
<td>62.2 ± 23.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Etiology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute respiratory failure</td>
<td>15</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>14</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Lung cancer</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular diseases</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Yes/No)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>12/37</td>
<td>29/42</td>
<td>0.4</td>
</tr>
<tr>
<td>Carbohydrateuria &lt; 10 g/dl</td>
<td>22/27</td>
<td>39/32</td>
<td>0.1</td>
</tr>
<tr>
<td>Propr, Blood transfusion</td>
<td>28/29</td>
<td>25/46</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 1. Characteristics of Patients Undergoing Bronchial Artery Embolization (BAE) for Life-Threatening Hemoptysis From 2000 to 2005

<table>
<thead>
<tr>
<th>Age</th>
<th>59.7 ± 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex ratio (M:F)</td>
<td>52:48</td>
</tr>
<tr>
<td>Underlying diseases</td>
<td></td>
</tr>
<tr>
<td>Old infection</td>
<td>24</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>12</td>
</tr>
<tr>
<td>Myasthenia</td>
<td>10</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>4</td>
</tr>
<tr>
<td>Necrotizing pneumonia</td>
<td>4</td>
</tr>
<tr>
<td>Arterio-venous malformation</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. Outcomes of Bronchial Artery Embolization (BAE) for Life-Threatening Hemoptysis Under Recent Therapeutic Strategy (2000–2005)

<table>
<thead>
<tr>
<th>Control of Hemoptysis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical success</td>
<td>(48/55/68%)</td>
</tr>
<tr>
<td>Control within 48 hours</td>
<td>(48/55/68%)</td>
</tr>
<tr>
<td>30-day Control</td>
<td>30/50 (76%)</td>
</tr>
<tr>
<td>60-day Control</td>
<td>31/43 (72%)</td>
</tr>
<tr>
<td>1-year Control</td>
<td>28/40 (70%)</td>
</tr>
<tr>
<td>Proceded to surgery after BAE</td>
<td>7/8 (13%)</td>
</tr>
<tr>
<td>Died after 30 days</td>
<td>14/43 (25%)</td>
</tr>
</tbody>
</table>

Pearls

1. ABC
2. Skills on lung isolation
3. Angiographic embolisation: excellent immediate control, semi-definitive Rx
4. Surgery: definitive, but high m/m; important to arrest bleeding with a non-surgical modality and stabilise the patient first, if possible, before a definitive surgical procedure
5. Understand merits and limitations of each modality, to make a rational clinical decision during Dx and Rx

Rasmussen aneurysm

- Hemoptysis occurs in a patient with cavitary tuberculosis
- Relapse of hemoptysis is observed after a technically good embolization by BAE
- In a few cases Rasmussen aneurysm, which results from the destruction of the media of segmental pulmonary arteries by granulation tissue
Arteriovenous malformation

- Hereditary hemorrhagic telangiectasia
- Rendu-Weber-Osler syndrome
- Simple (85%) or complex
- Congenital 75-95%
- Acquired 10% such as hepatopulmonary syndrome
- Hemoptysis (ruptured of aneurysmal sac),
  Stroke (paradoxical embolism), or severe respiratory compromise (shunting)
- Currently, if the feeder vessel has an angiographic diameter greater than 3 mm, selective pulmonary artery embolization is considered