Systemic air embolism in transthoracic needle biopsy: Risk factors, detection and management

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Objectives:

- To discuss risk factors in transthoracic lung biopsy.
- To practice detection with review of cases during procedure.
- To review step by step management, to improve outcome.
AIR EMBOLISM

- Air embolism: entry of air into vascular system.
- Systemic arterial air embolism: air occluding left heart / arterial circulation
- Physiological effects - from asymptomatic to fatal.

Factors determining the effect

- Vascular system/organ affected
- Delay in diagnosis / treatment
- Amount of air entered
Causes

- Trauma
- Obstetric - delivery
- Surgeries, Intervention, Injection, Biopsy
- Scuba diving
Systemic venous air embolism

Due to
- trauma,
- surgery
- venous access
- IV contrast injection

Tolerated

Systemic arterial air embolism

Most important

Feared
AIR EMBOLISM IN LUNG BIOPSIES

- Systemic arterial air embolism
  - More important and feared complication of lung biopsy.
  - Even very small amount (2-3 ml) of air can cause fatal end organ damage.

- Depend on the route of air entry to circulation
  - Pulmonary veins (PV)
  - Pulmonary arteries (PA)

- Less common because of higher pulmonary arterial pressure.
- Can be a potential source of systemic arterial embolism.
SYSTEMIC ARTERIAL AIR EMBOLISM

- A rare but feared complication of lung biopsy.

- Incidence: 0.02- 0.07%. One study reported up to 0.21%.

- In our hospital, 7 cases out of over 14,000 biopsies since 1999.

- Usually non-fatal / no long-term morbidity, if promptly suspected. However, could cause cardiac and neurological morbidities, if not diagnosed and managed promptly.

- Reports allude to good outcome with early use of hyperbaric oxygen chamber therapy (HBOT).
SYSTEMIC ARTERIAL AIR EMBOLISM: PATHOPHYSIOLOGY

Any factor establishing gradient and communication b/w between PV and potential air

2 ways of communication in needle biopsy

Between PV & room air via needle

Establish a gradient

inspiration ->

Between airways and PV via temp fistula

cough ->

Air entry in PV → left LA → LV

Air in systemic arteries

• Fatal damage in coronary and cerebral circulations:
  • Like MI, arrhythmias, Stroke etc.

• Small amount of air is tolerated in other organs like muscle or viscera

Thrombogenesis by platelet activation
Air induced vasospasm.
HIGH RISK FACTORS: PATIENT RELATED

Factors affecting healing of vascular injury - prolonged exposure of the vessel lumen to the airway

• Coagulopathy
• Inflammation
• Vasculitis, 
• Friable lung tissue due to pre-existing lung diseases

Diseases increasing airways pressure – establishing the gradient

• COPD
• Air trapping
• Pre-existing lung diseases.
• Cystic or cavitory lung disease
Sampling method: Core > FNA

Needle gauge
Large > small

Needle Positioning:
Piercing airways and PV

Patient lack of cooperation:
Movement, breathing, etc

Exposure to room air:
Through the needle

Lesion location
Central > peripheral

Based on expert opinion!
CLINICAL PRESENTATION – RAISING SUSPICION

Depend on involvement of organ specific circulation

Cardiovascular System
- Arrhythmias f/b changes of myocardial ischemia.
- Chest pain
- Hypotension
- Shock

Respiratory System
- Acute dyspnea, light-headedness, respiratory wheezing tachypnea

Central Nervous System
- Drowsiness, stroke-like facial and limb weakness
- Seizures
- Dysphasia

Any drop in level of consciousness (LOC) or neurological symptoms should highly raise the suspicion
IMMEDIATE MANAGEMENT

HIGH SUSPICION BASED ON SIGNS AND SYMPTOMS
Drop in LOC, Chest pain, Facial or body weakness, Seizure

Initial resuscitation
Position in right lateral decubitus
100% oxygen

Non contrast CT head + chest

Continue resuscitation, keep in right lateral decubitus, maintain on 100% oxygen

Once stabilized & diagnosis confirmed - transfer to hyperbaric chamber

Call ICU team / Rapid Assessment of Critical Events (RACE) team

Call hyperbaric oxygen chamber unit

Assessment and management measures as required
ROLE OF HYPERBARIC OXYGEN THERAPY (HBOT)

- HBOT is the **only effective treatment available** for arterial air embolism.

- It provides 100% oxygen at high pressure:
  - which dissolve the air within embolized bubbles by accelerated nitrogen resorption.
  - improve oxygenation of ischemic tissue.

- **Timing of HBOT:** a recent study showed **maximum effects within 4hrs** but some other mentioned in < 6hrs.
MECHANISMS OF ACTION OF HBOT

**Boyle’s law**
(the volume of a gas is inversely proportional to pressure)

- Decreases the size of formed bubbles in air embolus → relieving the mechanical obstruction

**Henry's law**
(the amount of a gas dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid)

- Increases dissolved oxygen in plasma that can seep through the obstruction.
- 100% oxygen decreases N2 concentration in the blood → draws N2 gas from embolus → decrease in size of air bubbles

**Other mechanisms**

- Decreases permeability of the blood-brain barrier → preventing cerebral edema.
- Decreases the adherence of leucocytes → preventing potential damage to the endothelium.
WHAT WE MUST KNOW

Why 100% oxygen on high pressure?
▶ Treats hypoxia and eliminate gas bubbles by establishing a diffusion gradient.

Why right lateral decubitus?
▶ The position keeps air bubble in non dependent part, superiorly away to left ventricular outflow tract (LVOT) i.e. decrease risk of entering to aorta.

Optimal position?
▶ Right lateral decubitus with head down / Trendelenburg – keeping head down prevent further entry of air bubble into cerebral circulation.
Why not supine as suggested by few authors?

In prone biopsies, lesions are usually peripheral non-dependent and pulmonary veins/left heart dependent. So, changing from prone to supine promote passage of air to systemic circulation.

Who is in first line of management?

Radiologist and assisting nurse.

What is different from systemic venous embolism?

Clinicians usually encounter the systemic venous embolism for which, optimal position is usually left lateral decubitus.
SIDE EFFECTS AND CONTRAINDICATION

**Absolute contraindication**
- untreated pneumothorax, as it may progress into tension pneumothorax.

**Relative contraindications**
- COPD, URTI, Claustrophobia, Eustachian tube dysfunction, pacemaker or epidural pain pump.

**Side effects**
- Claustrophobia, fullness in ears, temporary myopia, dry cough.
  - Evaluate on chest CT, If present place a chest tube.
  - keep ear pressure low, Maringotomy in non-cooperative patients.

**HBOT depending upon risk-benefit assessment**
CASES WE ENCOUNTERED

- The lung biopsies are done under CT or Fluoroscopy guidance.
- All biopsies done using the safest approach to get adequate diagnostic sample.
- A 19 G introducer and 22 G needle used for FNA sampling.
- 20 G coaxial needle used for core biopsy.
- Complications encountered were managed using multidisciplinary approach in a collaboration of radiology staff / nurses, neurology team, ICU team and Hyperbaric oxygen therapy unit.
- In all patients of air embolism with pneumothorax, a chest tube is placed before transferring them to HBOT.
Biopsy of a nodule close to a PV. 2 passes, no core.

Air in left atrium noted during biopsy. Patient was asymptomatic.

Air resolved after 10 hours of HBOT.

CT chest (patient with right side down): air bubbles in left ventricle.
Transthoracic needle biopsy, 2 passes, no core

CT after neurological symptoms developed during last pass
Air in LA and LV!

Air resolved, after 7 hours of HBOT

CASE - 2
Biopsy of a lingular nodule, 1 pass, no core

Air resolved after 10 hours of HBOT

CT done immediately due to seizures during procedure – air bubbles in right middle cerebral artery territory

CASE - 3
RLL nodule biopsy
2 pass, no cores

In 10 min chest pain and right sided weakness
CT chest: air in LV & coronary bypass graft.

Air resolved after 6 hours of HBOT

CASE - 4

S.S. Hare et al. / Clinical Radiology 66 (2011) 589-596
RLL nodule biopsy 5 pass, cores

Symptoms in 5 min (unresponsive to commands, systolic BP – 200 mmHg, right sided weakness

CT head: air in left ICA and posteriorly along sinus.

Air resolved in 6 hours of HBOT

CASE - 5
RLL nodule biopsy (3 passes + 4 cores)

Just after biopsy: chest pain and seizures

CT head & chest: air in LV and cerebral circulation

Air resolved after 8 hrs HBOT

CASE - 6

S.S. Hare et al. / Clinical Radiology 66 (2011) 589-596
LUL nodule biopsy (2 passes, no cores)

Chest pain and seizures post biopsy

CT chest: air in brachiocephalic vein, Aorta, RCA

Air resolved after 10 hours HBOT

CASE - 7

S.S. Hare et al. / Clinical Radiology 66 (2011) 589-596
Any decrease in GCS or neurological deficit should raise the high clinical suspicion.

Maintainance of vitals, right lateral decubitus positioning with steep head down and 100% high pressure should be prompt measure for immediate management.

An urgent CT of the brain and chest should be performed for confirmation.

HBOT is the only effective definitive treatment.

Rule out pneumothorax before shifting to HBOT; place a chest tube if present.
References:


Thank you

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