Intro to CXR for Non-Radiologists

**Objectives**

- Review anatomy & physiology of the heart & lungs.
- Understand the significant differences between:
  - Upright PA and lateral views
  - Portable supine AP view
- Recognize common abnormalities:
  - Pneumothorax
  - Pleural Effusion
  - Pneumonia
  - Pulmonary Edema

**Terminology: “Chest” X-Ray (CXR)**

- **X-Rays pass thru entire chest**
  - Superficial tissues
  - Skin, breasts, sub-q fat
  - Muscles
  - Intercostals
  - Bones
  - Ribs, sternum, spine
  - Heart & Mediastinum
  - Trachea, Vessels, ...
  - Lungs
  - Mostly air

**Radiographs Only Detect 4 Densities**

- Air = Black
  - Lungs (Air-filled alveoli)
- Soft Tissues = Gray
  - Superficial tissues
  - Heart, Mediastinum
- Bones = Lighter Gray
  - Ribs, Spine
- Metal = White
  - Outside/Inside patient

**Disclaimer**

- I am not a Chest Radiologist
  - This is my first CXR lecture
- I do read CXRs daily
  - Mostly from the ER
- Reading CXR is something all radiologists should be able to do
  - Mostly from the ER
- Looking at CXR something ALL health care providers should be willing to do

**Terminology: Chest “X-Ray” (CXR)**

- This is a “Radiograph”
- Recall, “X-Rays” are:
  - EM Spectrum energy
  - Very short wavelength
  - About size of an atom
  - Man-made
  - Emitted by a tube...
  - …pass thru patient…
  - …into a x-ray detector
  - Film (old school)
  - CR plate
  - DR unit

**Convention: We look at CXR like we look at Pt… Face-to-Face**

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**Introduction to CXRs**

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**PowerPoint Model: Lungs**

- **Physiology**
  - **Anatomy**
    - **DualEnergy**
      - **LookingCXR**
        - **Normal**
          - **PTX**
            - **Pl.Effusion**
              - **Pul.Edema**
                - **WOW**

**Introduction to CXRs**

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**How Do The Lungs Work?**

- **The lungs don’t “work”** (just bags of air)
- Lungs inflate *passively* in response to pressure gradients
  - Carina Pressure > Lung Pressure
  - Rescue Breathing
  - On a ventilator
  - Tracheal Tube
  - Lung Pressure < Carina Pressure
  - Negative pressure outside the lungs
  - Created by the DIAPHRAGM

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**Lungs Work The Same**

- **2 Lungs** (bags of air)
- **Tracheobronchial tree**
- **Sealed within Thorax**
  - **Ghost Wall** (layers)
    - **Skin/Sub-Q**
    - **Ribs, Intercostal A/N/Muscles**
    - **Inner Pleural Lining**
  - **Diaphragm – Domed**
    - **Increases intra-thoracic volume**
    - **Decreases intra-pleural pressure**

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**Lungs Fill Pleural Space**

- **Not much in Thorax**
  - **Lungs: Fill the Thorax**
    - **From Apices**
    - **Costo-Phrenic Angle (CPA)**
      - **“Costo”**: Ribs
      - **“Phrenic”**: Diaphragm
  - **Tracheobronchial Tree**
    - **Bronchioles branch off**
    - **Heart**
    - **Vessels (Mediastinum)**
    - **Connect lungs to heart**
    - **Connect heart to whole body**

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**Introduction to CXRs**

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**Thought Experiment**

- Balloon tied to a Straw
- Sealed inside glass jar
  - Only way air gets into balloon is via end of straw outside jar
  - Jar has sealed rubber bottom
  - Pulling down on bottom...
    - Increases size of sealed jar
    - Decreases pressure in jar (Pv=nrT)
    - Jar Pressure < Atmospheric
    - Balloon inflates!

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**Gas Exchange**

All human cells require O\(_2\), emit CO\(_2\). Red Blood Cells (RBC) transport gas.

- Hemoglobin molecule (Hgb)
- Occurs at capillaries
  - Diameter = 1 RBC (5µm)
  - Walls: Very thin, semipermeable membranes
  - Permits Diffusion of gasses

**Diffusion**

Way of moving things for free. (No energy expense)
Related to a Fundamental Force: Entropy
- Things become disorderly
- “It takes a lot less energy to knock down Jenga tower…
Here’s some of mine”

**Gas Exchange: Alveoli**

- alveolus [L]: “little cavity”
- Air sacs
- Bronchioles
- Looks like bunch of grapes.
- Interstitial spaces
  - Outside alveoli
  - Capillaries
  - Where gas exchange occurs

**The Heart: 4 Chambers**

- Arteries carry blood from Heart
  - Thick walls (>120mmHg)
- Veins carry blood to Heart
  - Thin walls (<10mmHg)

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Also vessels, Descending All blood/contrast filled Oblique view CT obtained immediately
Basic 3D processing…
Right Subclavian LV
Similar to bone density

Aorta
Thick wall, 3 layers
\( \text{Intima (inner layer)} \)
\( \text{Media (muscle, elastic fibers)} \)
\( \text{Tear \rightarrow \text{Aneurysm}} \)
\( \text{Adventitia (outer, supportive layer)} \)
\( \text{Tear \rightarrow \text{Aortic Laceration}} \)
Can’t see this with CXR
Need to use: CT, MR, US

\( \text{LV} \):
Workhorse of the heart
Thick muscular wall
Pump blood to entire body
Generate pressure >120mmHg
5½ FEET of \( H_2O \)
It doesn’t look like much here because this is a CTA, showing only the contrast in the blood.
Radiograph – LV:
left cardiac border
cardiac apex

\( \text{PA} \):
Wraps around LV
Thin muscular wall
Only needs to pump blood to adjacent lungs (20mmHg)
Pulmonary Artery (PA):
Carries blood from RV to both lungs
Only artery to carry deoxygenated blood

\( \text{RA} \):
Forms right heart border on CXR
Wraps around RV
Doesn’t contribute to heart shadow on frontal radiograph

\( \text{PTX} \):
Normal
Pulmonary Edema
Pul Edema
WOW

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Introduction to CXRs

For Non-Radiologists

Upright PA Chest Radiograph

Standing Upright
- This is a big deal
- Permits full lung inflation
- Can't fully inflate laying/sitting
- Makes use of gravity
- More blood flows to bases
- Pleural effusions "bump" at lung angles
- Pneumothoraces "plop" apices
- Pulls scapulae away
- Patient hugs detector

Marty age 13

Introduction to CXRs

Shadow-graphic Magnification

As my hand gets further from the wall, the shadow gets larger

Flashlight

Similarly, as body parts get further from the detector, their radiographic shadow get larger

Introduction to CXRs

PA CXR is Backward

Shot looking at patient's back...
Hung looking at patient's front

Outpatient Clinic

1 hour later, Emergency Room

Importance of Scapular Abduction

Pneumothorax!

Scapula overlaps lung

Can't see the PTX!
Introduction to CXRs for Non-Radiologists

Physiology
Anatomy
PA & LAT.
Dual Energy
Portable AP
Looking at CXR
Normal
PTX
Pleural Effusion
Pneumonia
Pul Edema
WOW

Importance of multiple views
- Patient standing
- Lungs inflated
- Left side next to the detector
- Minimize heart magnification
- Traditional: Hung backwards
- Arms Elevated!

Importance of Arm Elevation
- Arms not elevated
- Can barely even see the heart
- Repeat Lateral View
- Repeat Lateral View

Importance of Lateral View
- Obvious density Behind heart = LLL Pneumonia
- Subtle density Overlaps heart

CXR is NOT a Simple Exam
- Requires patient able to:
  - Stand upright
  - Sitting in a chair is not the same
  - Propped up on a cart, not the same
  - Elevate their arms, abduct scapulae
  - Take in a big breath, hold it 1 second

Requires technologist to:
- Make sure patient is optimally positioned
- Look at images to assess optimal quality
- Repeat images as needed

Dual Energy CXR: Separate Lungs/Bones
- The lungs are hard to see on CXR as they are nearly radiolucent, compared to the overlying bones which are relatively radiopaque.
- Wouldn’t it be nice if we could remove calcified ribs on a CXR...
generating a 2nd CXR of the lungs without the overlying ribs...
even generate a 3rd CXR showing just calcified structures!

At UW, our standard PA CXR is Dual Energy
Requires investment in dedicated DR unit

Digital Radiography
- CR (Computed Radiography): Similar to old-fashioned film radiography
  - Technologist places a cassette under the patient
  - Contains photostimulable phosphor plate, rather than film
  - Laser scanner, rather than darkroom chemical developer
  - Used for bones, abdomen, portables

- DR (Direct Radiography): Similar to modern digital camera
  - Captures directly to image detector, no cassette
  - Captures 2 images, rapidly, at 2 energies (DE)
Introduction to CXRs

For Non-Radiologists

CR: Can use old film equipment

Outpatient CR room

> Same film equipment
>
> Same X-ray tube
>
> Same cassette holder

CR: Film, cassettes, dark room replaced

Outpatient CR room

> Same film equipment
>
> Same X-ray tube
>
> Same cassette holder

WOW

CR cassettes containing the phosphor plates

IIP plate reader

DR: Requires all new equipment

Outpatient DR room

> It looks a lot like the CR room
>
> New dual energy X-ray tube
>
> New DR detector built into table
>
> Built into upright chest unit

Dual Energy CXR: Helps See Pneumonia

Standard PA view

Dual Energy Lung view

Hard to see subtle density overlapping ribs...

D,K 63yoM

Calcified Granuloma

Dual Energy CXR: Helps See Nodules

Standard view

Lung view

Lung view

L,T 61yoM

Calcified Granuloma

Dual Energy CXR: Shows Ca++ Nodules

Standard view

Lung view

Calcified Granuloma

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**Portable Supine AP CXR**

Used in cases when patient cannot stand for upright PA & Lateral views

**Supine AP: Can’t make use of Gravity**

Upright PA

PTX rises above normal lung

Supine AP

PTX layers out posterior to normal lung

 Portable AP CXR Never Fully Upright

O,T 54yoM

Semi-upright AP

Upright PA

Lungs better inflated

Heart less magnified

Normal pulmonary markings

Dx: Normal

**Problems with Supine AP vs PA**

- X-ray beam not perpendicular to gravity
  - Hard to see PTX air rising anteriorly
  - Hard to see pleural effusions layering out posteriorly
  - Hard to assess increased blood flow to upper lobes
- Lungs never well inflated
  - No lateral view
  - No dual energy
  - Hard to abduct scapulae
  - Heart is magnified
    - Harder to assess heart size (cardiomegaly)

**Portable AP vs Upright PA**

Semi-upright AP

Heart looks too big

Lots of pulmonary interstitial markings

Extending to periphery!

Dx: Resembles Pulmonary Edema?

Rec: Upright PA & Lat.

Upright PA

Lungs better inflated

Heart less magnified

Normal pulmonary markings

Dx: Normal

**Portable AP vs Upright PA**

A.R 76yoM

Semi-upright AP

Upright PA

Lungs better inflated

Heart less magnified

Normal pulmonary markings

Dx: Normal

**Portable AP vs Upright PA**

O,T 54yoM

Semi-upright AP

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Dx: Normal

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Intro to CXR for Non-Radiologists

Portable AP vs Upright PA

OK to travel to DR

Portable AP vs Upright PA & Lat

Portable AP CXR Good For?

What is the Portable AP CXR Good For?

What is the Portable AP CXR Good For?

What is the Portable AP CXR Good For?

What is the Portable AP CXR Good For?

Break... then Key things to look for...
Schreibman’s Says...

1st Rule of Radiology:
Know what you’re looking at!

Is this the correct study? (YOU check every time)
- Correct Patient
- Correct Date/Time
- Correct Study (CXR ≠ CT ≠ MR ≠ US)
- Correct Body part

Is this a good study? (This takes experience)
- Is it upright PA & lateral, or portable supine AP?
- Is this a good quality study?
  - Patient well positioned? Lungs well inflated?

Are the Lungs fully included?

From Apices to CP Angles on Lateral!

Are Lungs Well Inflated?

Old Radiology Lore:
- The lungs are well inflated if you can see 10 ribs.
- I can’t find a reference

Air Below Diaphragm

Common below LEFT
- Stomach
- Colon (Splenic flexure)

Uncommon below RIGHT
- That’s where the liver lives (hepatic flexure)
- Child’s (‘Kylling-Meckel’)

Free air below diaaphragm is Abnormal
- Recent (past week) surgery, laparoscopy
- Bowel Perforation!
  (Pneumoperitoneum)

Air Below RIGHT Diaphragm

Liver
Stomach→ Colon

Free Air!

Are the Lungs fully included?

From Apices to CP Angles on Lateral!

Are Lungs Well Inflated?

Patient is instructed:
- “Breathe in… hold it…”
- Tech shoots picture
- “… and breathe…”

We want lungs maximally inflated

Old Radiology Lore:
- The lungs are well inflated if you can see 10 ribs.
  (I can’t find a reference)
**Intro to CXRs for Non-Radiologists**

**WOW**

- **Good Inspiration (even on Portable Supine AP)**
- **Physiology**
- **Anatomy**
- **PA & LAT.**
- **Dual Energy**
- **Portable AP**
- **Looking @ CXR**
- **Normal**
- **PTX**
- **Pleural Effusion**
- **Pneumonia**
- **Pul Edema**
- **WOW**

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**Physiology**

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**Lung Anatomy: Lobes & Fissures**

- **Right Lung**
- **Major Fissure**
- **Minor Fissure**
- **Upper Lobe (UL)**
- **Lower Lobe (LL)**
- **Major Fissure**
- **Minor Fissure**
- **Upper Lobe (UL)**
- **Lower Lobe (LL)**
- **Minor Fissure**
- **RUL**
- **RLL**

---

**Look for sharp margins**

- **Heart borders**
- **Diaphragm**
- **CPAs**
  - Should be sharp enough to pick your teeth!
  - Lateral too...

---

**Look behind heart/diaphragm**

- **Try to see lung marking behind heart/diaphragm**
  - May need to re-window
  - **Pneumonia**
  - **Aspiration**
  - **Pleural Effusions**

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Pneumothorax!

Air in the thorax…
outside the lung
▶ Air in the pleural space
✓ (Here illustrated in orange)

There should be
NOTHING pleural space
▶ Literally a vacuum
▶ The more the pleural space
fills with air outside lungs
there’s less air inside lungs

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PTX: Penetrating Trauma

Air = Black

Edge
Left
Lung

Subcutaneous Air (Emphysema)

WOW

Lesson Icon

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PTX: Penetrating Trauma

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PTX: Rib Fracture

Dennis
Lung view

Dual Energy Rocks!

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PTX: Rib Fracture

Dennis
Lung view

Dual Energy Rocks!

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PTX: Spontaneous

Primary Spontaneous PTX
▶ Absence of underlying lung disease
▶ Tall (76”), male (3-6x), smoker (22x)

Secondary Spontaneous PTX
▶ Underlying lung disease
✓ Chronic Obstructive Pulmonary Disease (COPD): 70%
✓ Bullae rupture

Death from PTX is uncommon (1.10⁻⁶)…
except in TENSION PNEUMOTHORAX!

Physiology
Anatomy
DualEnergy
PortableAP
Looking@CXR

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PTX: Spontaneous

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PTX: Tension Pneumothorax

Subcutaneous Air (Emphysema)

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PTX: Tension Pneumothorax

Subcutaneous Air (Emphysema)

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*Pleural Effusion*

Just as PTX is air in pl. space
- Risks to apex on upright
- Flows to bases/CPA on upright

Can be due to:
- Lung disease
  - Infection, PE, Malignancy
- Heart disease
  - Congestive Heart Failure (CHF)
- Abdominal disease
  - Hepatic cirrhosis, Nephrotic syndrome

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*Pleural Effusion: Meniscus*

Similar to water flowing up the glass...

**Pleural effusions flow up chest wall**

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*Pleural Effusion: Silhouette Sign*

Basic Radiology Concept:
- We see edges when adjacent structures are different density
  - We can see left heart border
    - Heart (tissue density) / Lung (air density)
  - We can see left hemidiaphragm
    - Diaphragm (tissue density) / Lung (air density)
  - We cannot see RIGHT heart border
    - Heart / Pleural Effusion (both tissue den.)

*The pleural effusion is silhouetting out the right heart border and hemidiaphragm*

---

*Pleural Effusion + Fissures*

Left side-down decubitus view

- Free Flowing Pleural Effusion
  - Layering out

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*Pleural Effusion: Loculated*

Left side-down decubitus view

- Pleural Effusion NOT Layering out

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Anatomy

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Pleural Effusion: Fluid outside lung

- CXR: Tissue density (Silhouettes heart/diaphragm)
- Dependent on upright & decubitus views
- Sharp meniscus border

Pneumonia: Fluid inside lung (Alveoli)

- "Air Space Disease"
- CXR: Tissue density (Silhouettes heart/diaphragm)
- Lobar (segmental) distribution
- Fuzzy border

WOW

Air Space Disease: Right Lower Lobe

Physiology

Anatomy

DualEnergy

Looking@CXR

Normal
PTX
Pl. Effusion
Pneumonia
Pul Edema

S,M 8yoM

Upright PA

Upright Lateral

Air Space Disease: Left Lower Lobe

Physiology

Anatomy

DualEnergy

Looking@CXR

Normal
PTX
Pl. Effusion
Pneumonia
Pul Edema

S,R 74yoM

Upright PA

Upright Lateral

Air Space Disease: Right Middle Lobe

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Normal
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Pl. Effusion
Pneumonia
Pul Edema

B,D 49yoM

Upright PA

Upright Lateral

Air Space Disease: Left Lower Lobe

Physiology

Anatomy

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Normal
PTX
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Pul Edema

S,R 74yoM

Upright PA

Upright Lateral

Importance of Lateral view!

Density behind heart
(Can't see lung markings thru them).

Density over spine
"Spine Sign"
LL ASD

PNEUMONIA NEEDS TO
BE FOLLOWED UNTIL
RESOLUTION!
Pulmonary Edema: Spaces

- Pleural Effusion: Fluid outside lung
  - Pleural Space

- Pneumonia: Fluid in lung
  - Air Space (Alveoli)

- Pulmonary Edema: Fluid in lung
  - Interstitial Space
  - Fluid leaks from capillaries
    - Interstitial Space → Alveoli → Pleural Space

Pulmonary Edema: Fluid Overload

- Pulmonary Edema: Cardiogenic
  - With Congestive Heart Failure (CHF)
    - LV doesn't pump well (doesn't empty well)
    - Blood gets backed up in LV
    - LV dilates (chamber enlarges, wall thins)
    - Blood backs up in LA (enlarges)
    - Blood backs up in PV → Lungs
    - Engorgement of pul. vessels
      - Upper lobes
    - Fluid leaks from capillaries → Interstitial Space

Multi Chamber Cardiomegaly

- Evolution of CHF
  - 2009: Baseline
  - 2010: Needs O2
  - 2011: Needs Pacemaker
  - 2012: Pulmonary Edema
What to Order When (WOW)

**Chest: PA & Lateral Upright views**
- This is the standard exam for the lungs
- Lungs maximally inflated
- Heart magnification minimized
- Importance of multiple views
- Useful to see:
  - Pneumonia (air space disease)
  - Pneumothorax (+/- "tension")
  - Congestive Heart Failure (CHF)
  - Pleural Effusion
  - Cardiomegaly
  - Increased interstitial markings

**CXR: Charges**

**UWHC 2013 Charges**
- PA & Lateral views: $227
- Dual Energy PA & Lateral: $227
- Portable AP view: $203

What to Order When (WOW)

**Chest CT (Computed Tomography)**
- Best way to see inside lungs
- Following up suspicious things seen on CXR
- Working up pulmonary nodules, tumors
- Can see tiny PTX, Effusions missed on CXR
- But are these tiny things really a problem???
- Workup chronic interstitial lung disease
- Ordered by Pulmonologist
- Chest CT = 3 years background radiation
- Don't want to order too many serial Chest CTs too close together

**Pulmonary Emboli**

**Life Threatening Condition**
- Blood clots in legs veins are common
- Deep Venous Thrombosis (DVT)
- If a clot breaks loose, it travels up the veins, entering larger veins (won’t get stuck), entering the vena cava → right heart, travels through main pulmonary artery, finally getting trapped in smaller arteriole.
- No gas exchange occurs off that arteriole
- If embolus is large enough, it will prevent gas exchange in a large percentage of the lung.

**Can’t Diagnosis with CXR!**
- CXR may show non-specific findings
- CXR may be normal!

**Nuclear Medicine (VQ Scan)**
- Angiograms (Aorta, Pul.Art.)
- We don’t do these anymore
- Been replaced by CT-A (MR-A)
Introduction to CXRs

What to Order When (WOW)

Chest: CT-A (CT-Angiography)
- Rapid IV contrast bolus to see blood vessels
- Increasingly frequently being ordered in ER
- To rule out life threatening conditions:
  - Pulmonary Embolism
  - Traumatic Aortic Laceration
  - Aortic Dissection
- Also gives very nice look at lungs
  - Don’t need to order a Chest CT if you are already getting a Chest CT-A
- 3 years radiation + large IV contrast bolus

Introduction to CXRs

Any Questions?

Chest MRI / MR-A
- Ordered much less frequently than CT
  - More issues with MR, longer scan time
  - At progressive imaging centers, like UW, very good at seeing inside blood vessels
  - Can be used to see Pulmonary Emboli!
  - Without Radiation!
  - Used in young women to avoid rad. to developing breasts (Birth Control Pills are a risk for forming Pulmonary Emboli)
  - Without Iodine-Based Contrast!
  - Used in patients with allergies or renal issues

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