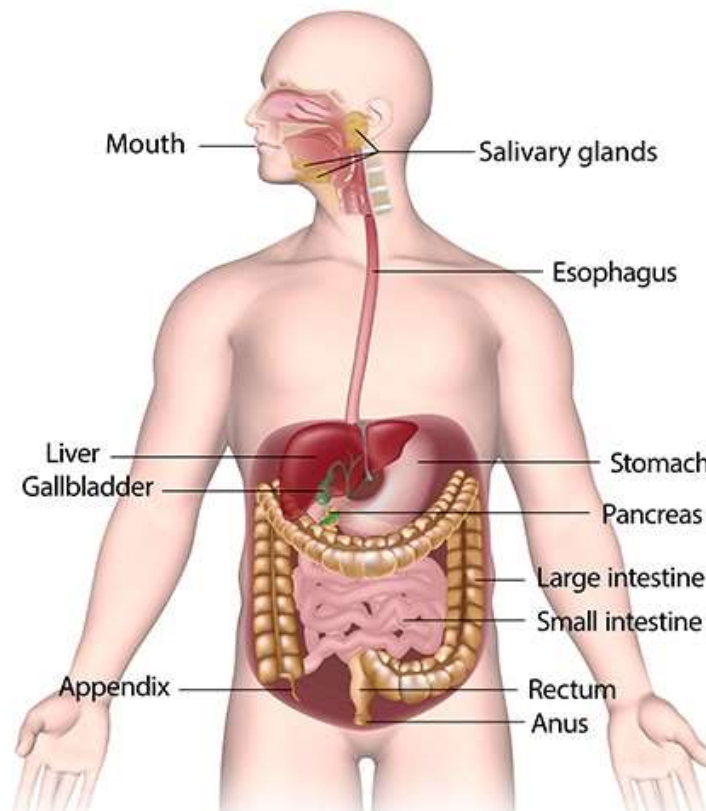


# **GASTROINTESTINAL TRACT**

Nuclear Medicine Scans: Analysis of uptake mechanism and imaging protocols

## The Digestive System



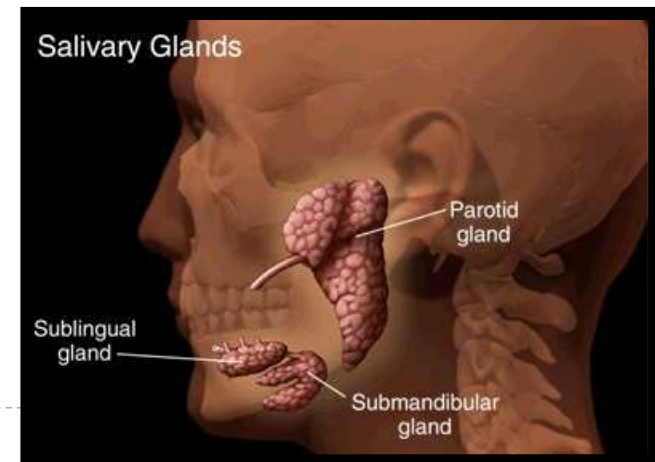
A dark blue vertical bar is positioned on the left side of the slide, spanning the height of the first rectangular box.

## **Upper gastrointestinal tract**

A light blue vertical bar is positioned on the left side of the slide, spanning the height of the second rectangular box.

# Salivary glands

- ▶ 3 type of cells from which they are consist of: serous, mucous and mixed.
- ▶ Small salivary glands (700-1000) are located in the submucosal layer of the walls of the oral cavity and pharynx.
- ▶ Major salivary glands (three paired glands) ear or parotid gland (gl. parotis) 33-85 mm submandibular (gl. submandibularis) sublingual (gl. sublingualis)
- ▶ Production and excretion of saliva via intralobar ducts (epithelial cells)



## INTRODUCTION

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- ▶ Scintigraphic methods: diagnosis of space-occupying lesions of salivary glands, and the study of functional disorders.
  - ▶ A patient complaining of vague symptoms related to the salivary glands but with no definite sign of an abnormality.
  - ▶ Radiographic exam: discomfort and radiation exposure
  - ▶ In this situation, scintigraphic studies are a valuable and reliable alternative: **morphology** of all major salivary glands and minor impairment of glandular **function**.
- 



## SCAN TECHNIQUES

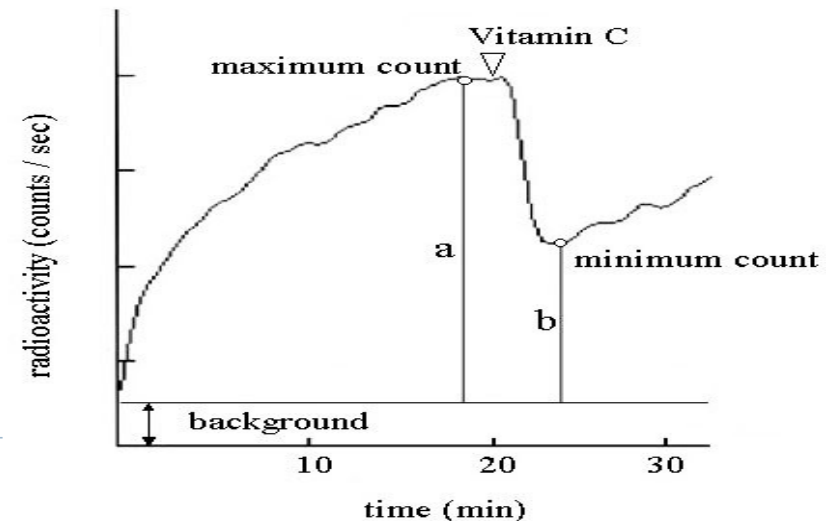
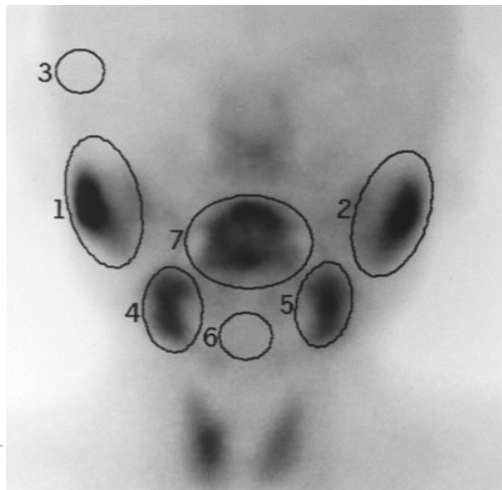
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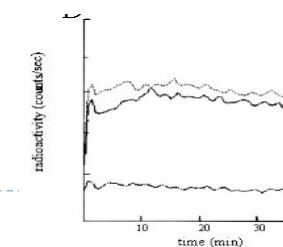
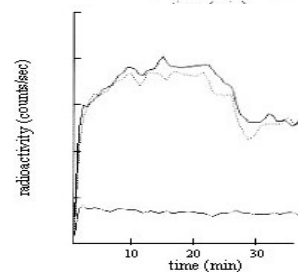
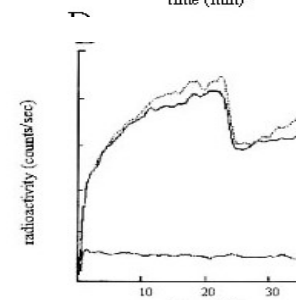
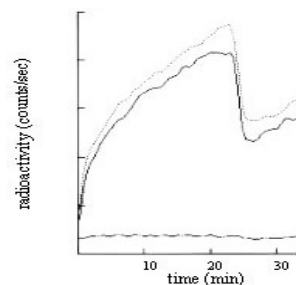
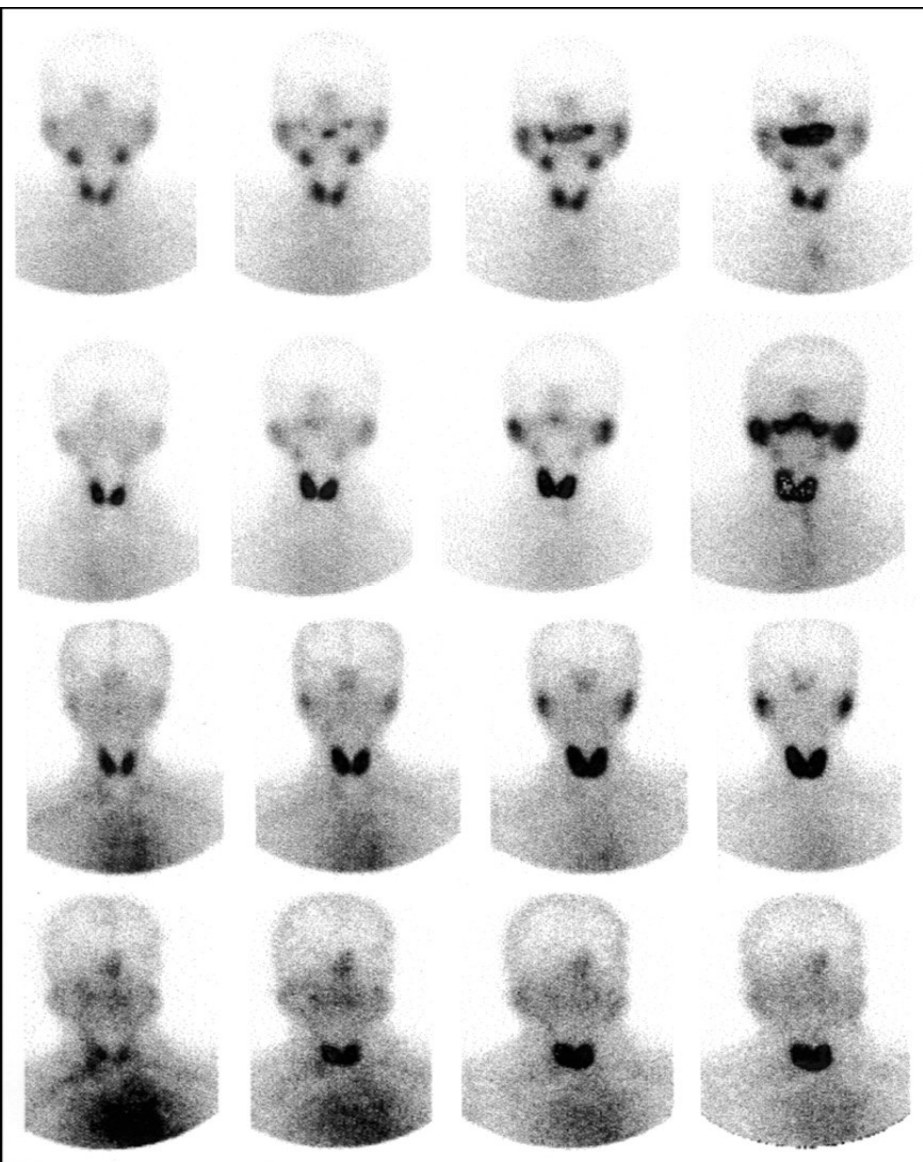
- ▶ Both static and dynamic studies
- ▶ Supine position under a gamma-camera
- ▶ 148 MBq of  $^{99m}\text{TcO}_4$ , IV injection
- ▶ 2 min frames, for a total of 40 min. at the 20<sup>th</sup>, the patient is requested to suck on the juice of a lemon by a straw



## SCAN TECHNIQUES

- ▶ ROIs are selected over **parotid** and **submandibular glands** and corresponding time-activity curves are created ( Fig )
- ▶ Numerous semiquantitative parameters have been described.
  1. **T<sub>max</sub>** : the time of maximum radioactivity
  2. **E<sub>5</sub>%**: at the 5<sup>th</sup> min after T<sub>max</sub> as a percentage of max





Salivary gland scintigraphy stages depend on salivary gland uptake and excretion:

- ✓ stage 1, normal uptake and excretion;
- ✓ stage 2, mild to moderate dysfunction;
- ✓ stage 3, moderate to severe dysfunction;
- ✓ stage 4, severe dysfunction.



# SALIVARY GLAND PATHOLOGY

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## Inflammation

### ▶ Acute sialadenitis ( bacterial or viral )

1. Increase in radionuclide uptake ( hyperactivity) is by the **hyperemia** of infection and by **edema** compressing the intralobar ducts.
2. A **steep** initial rise in TAC
3. Early : shortened Tmax, normal E5%
4. Late : Tmax may be normal, E5% prolonged

### ▶ Chronic sialadenitis

1. Chronic sialadenitis are variable and depend on the stage of inflammatory process.
2. Flattening of the curve together with a progressive decrease in scintigraphic outline. ( fig 34.3 )



## Sjogren's syndrome

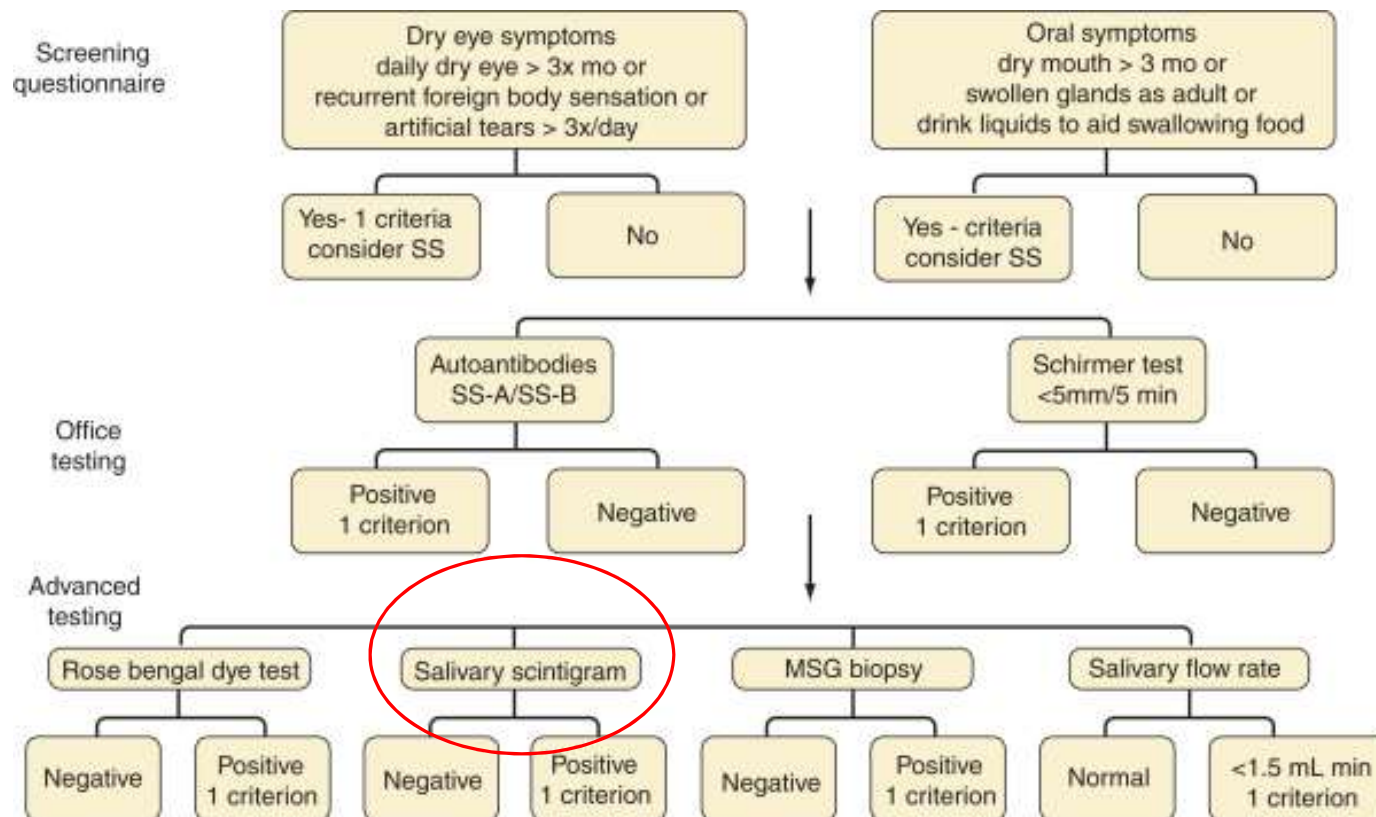
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- ▶ Sialoscintigraphy, dacryoscintigraphy, and  $^{67}\text{Ga}$  scintigraphy in the diagnosis and post-therapeutic follow-up of Sjogren's syndrome.
- ▶ Sialoscintigraphy alone is unable to distinguish between a simple *chr. Inflammation* and *the syndrome*. However, the **simultaneous presence of a high  $^{67}\text{Ga}$  concentration in lacrima and salivary glands** is pathognomonic for Sjogren's syndrome ( fig34.4 )
- ▶  $^{67}\text{Ga}$  is strongly suggested in the follow up of drug therapy( anti-autoimmune ), 1 month after drug therapy.

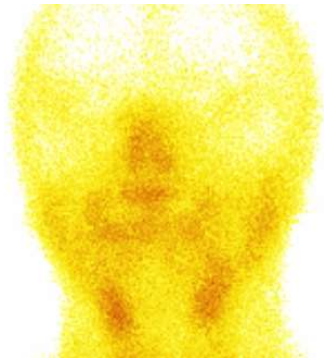


# Sjogren's syndrome

## American-European consensus criteria for the diagnosis of Sjögren's syndrome



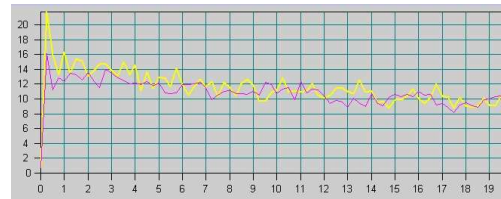
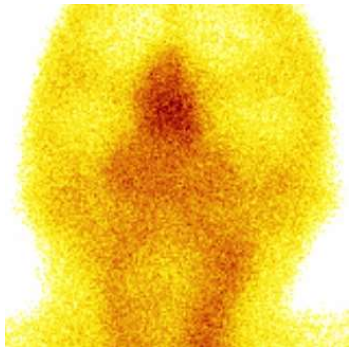
# Sjogren's syndrome



parotid glands



submandibular glands



parotid glands



submandibular glands

## Sequelae of cervical irradiation

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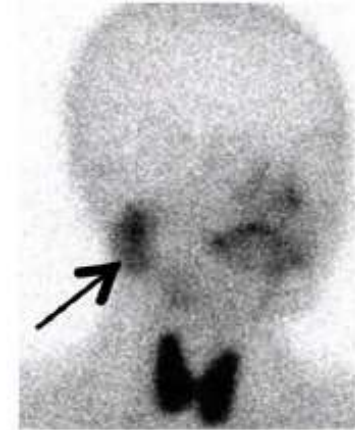
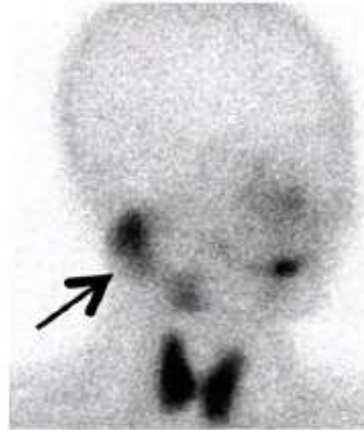
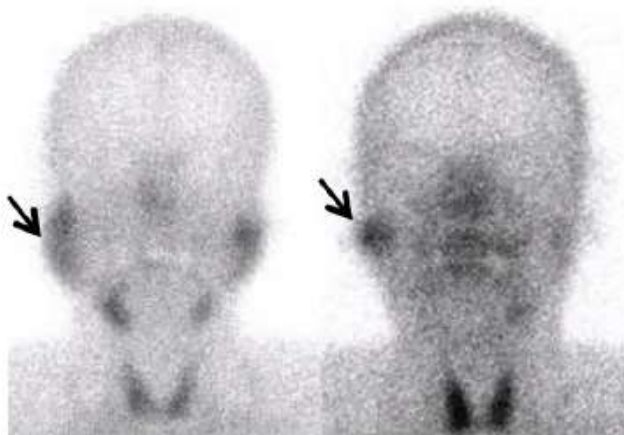
- ▶ Impairment of salivary glands following a course of R/T ( head & neck cancer ) or  $^{131}\text{I}$  irradiation ( thyroid carcinoma )
- ▶ Using time-activity curves and semiquantitative parameters, a dose-response relationship for salivary gland function can be determined.
- ▶ For example: ( thyroid cancer )
- ▶ If an acute or subacute sialoscintigraphic pattern of inflammation is found, the initial  $^{131}\text{I}$  administration is delayed for a cycle (5-7days) of anti-inflammatory therapy. This allow a **partial recovery** of excretory function.



# Tumors

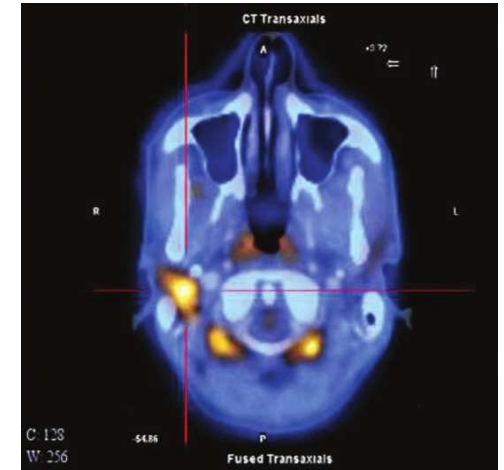
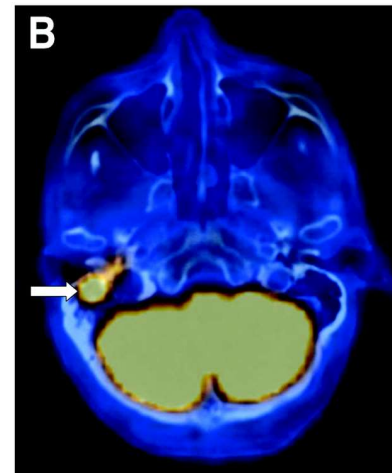
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- ▶ The diagnosis of a salivary gland tumor cannot be made by sialoscintigraphy since a cold area is the constant pattern, whatever the nature of the neoplasm.
- ▶ Only exception : Warthin,s tumor and some oxyphilic adenomas increased uptake of radionuclide.



# $^{18}\text{F}$ -FDG PET/CT

## Malignant tumors

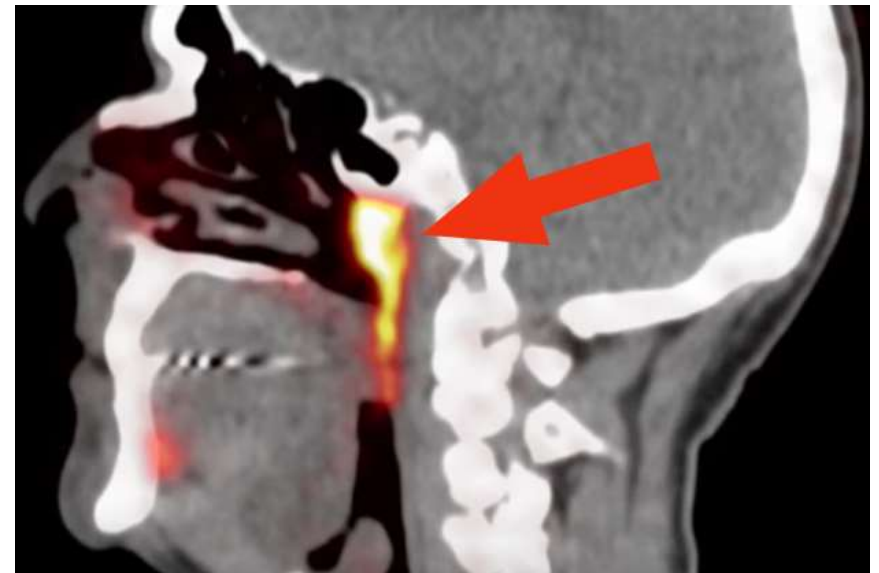
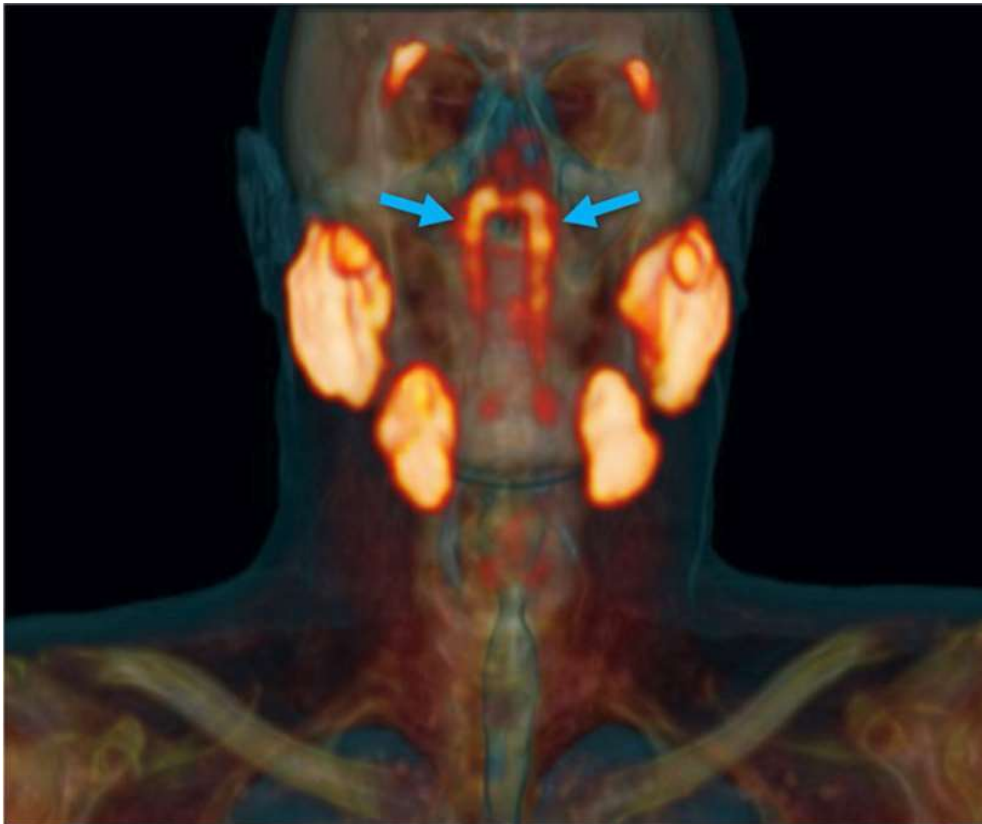




SCIENCE

# New pair of salivary glands in humans discovered

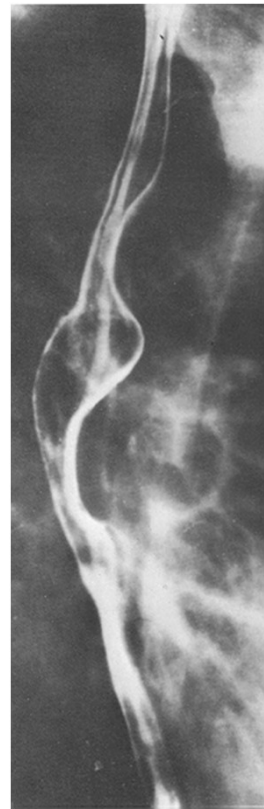
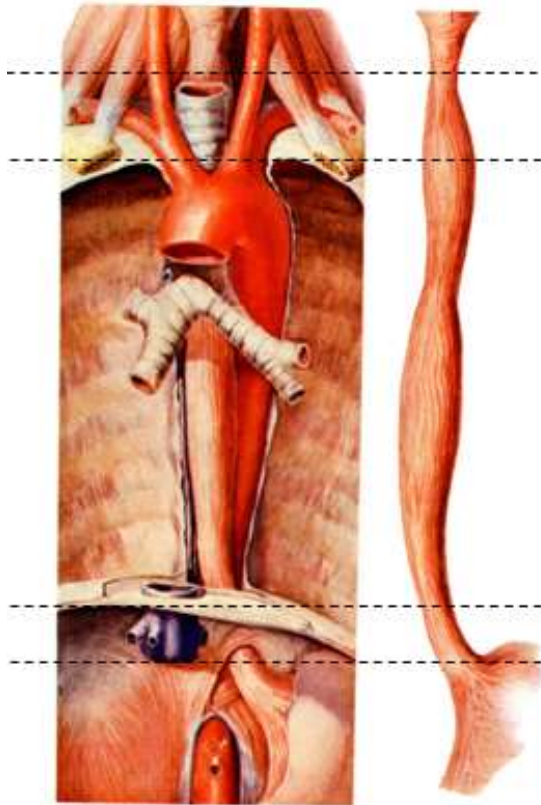
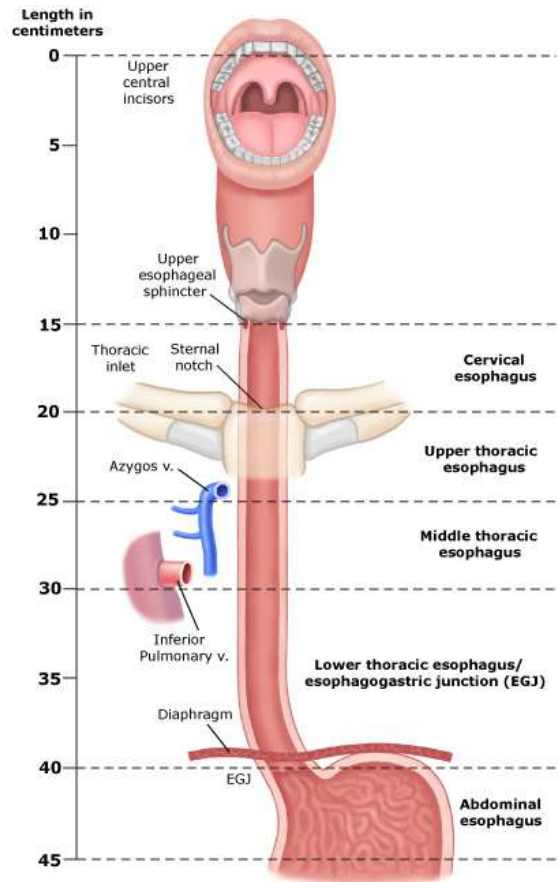
PSMA PET-CT



(Valstar et al., Radiotherapy and Oncology, 2020)



# Esophagus



# Anatomy of The Esophagus

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- ▶ The esophagus is a hollow muscular organ, approximately 25cm in length that extend from the pharynx to the stomach
- ▶ **Cervical Esophagus:** Just lies to the left of midline behind the larynx and the trachea. The entry to esophagus called upper esophageal sphincter (UES).
- ▶ **Thoracic Esophagus:** The upper part passes behind the carina & Lt. main stem bronchus. The lower part passes behind the left atrium.
- ▶ **Abdominal Esophagus:** Is the smallest portion of the esophagus (2-4cm length). It has lower esophageal sphincter (LES)- non anatomical with normal resting pressure 10-20mmHg.
- ▶ **Normal esophageal narrowing:**
  - UES at the level of cricoid cartilage 14mm in diameter.
  - Broncho-aortic constriction 17mm in diameter.
  - LES (19mm) as it travels the diaphragm & located 3-5cm at distal part of the esophagus.

# Esophageal Motility Disorders

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- ▶ **Achalasia**
- ▶ **Spastic esophageal motility disorders** such as
  - ❖ diffuse esophageal spasm
  - ❖ nutcracker esophagus
  - ❖ hypertensive /hypertrophic LES
  - ❖ Non-specific esophageal motility disorder
  - ❖ presbyo esophagus
- ▶ **Secondary esophageal motility disorders** related to , diabetes, alcohol consumption,collagen,endocrine and neuromuscular diseases.



# Esophageal Motility Disorders

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## ▶ Achalasia (failure to relax)

- Is the only esophageal motility disorder with an established pathology.
- The predominant pathophysiology of achalasia is the **loss of Auerbach** ganglion cells from the wall of the esophagus ,starting at LES and progress proximally.
- Incidence is 1-3 / 100,000 population / year.
- Characterized by failure of LES to relax completely during swallowing
- ▶ Primary and secondary peristalsis initially fails, tertiary contractions develops ,leading to stasis of food and subsequent dilatation.
- Manometry may reveal elevated LES pressure  $> 40$  mmHg in 60% of patients.



# Esophageal Motility Disorders

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## SPASTIC ESOPHAGEAL MOTILITY DISORDERS

### Diffuse esophageal spasm (DES):

This is probably related to fragmental degeneration of vagal nerve fibers.

- Characterized by simultaneous, repetitive high pressure muscular contraction within the esophagus.
- May be associated with severe intermittent chest pain, dysphagia and even food impaction.



# Esophageal Motility Disorders

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- ▶ **Scleroderma esophagus**
- ▶ Collagen vascular disease.
- ▶ Vasculitis damages the smooth muscle coat of the bowel and mainly involve the distal 2/3 of esophagus.
- ▶ Muscle damage results in a loss of primary and secondary motility , development of tertiary contractions and weakening of LES causing GERD.



# Scintigraphic tests

## THE TRANSIT TEST

have been shown to be more sensitive than endoscopy radiography and manometry in the identification of patients with motility problems.

Disorder	Sensitivity (%)	Specificity (%)	Positive predictive value (%)
Esophageal transit scintigraphy			
Achalasia	91	98	95
Diffuse esophageal spasm	33	99	67
Scleroderma	75	99	75
LES dysfunction	25	99	67
NSEMD	71	76	48

# THE TRANSIT TEST

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- ▶ The transit test demonstrates oesophageal function by visualising the passage of a swallowed bolus into the stomach.
- ▶ The labelled material may be prepared in either liquid or solid form – for example, orange juice labelled with  $^{99m}\text{Tc}$ -DTPA
- ▶ Each swallow consists of one mouthful (8-10 ml) of the labeled material and is swallowed in a single gulp, the patient being asked not to swallow again for the next 30 s, during which time the image acquisition is made.(2-4 frames per second).





# THE TRANSIT TEST

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- ▶ The images can then be displayed as a cine loop, and time-activity curves derived for the upper third, middle third, lower third and whole oesophagus.
- ▶ Typically, three consecutive swallows may be obtained in the supine position, and a further three swallows in the sitting position. Between each swallow the oesophagus is rinsed with an unlabeled drink in order to clear residual activity
- ▶ The results can be expressed either qualitatively, or by using a grading system, or by measurement of the mean transit time between mouth and stomach.

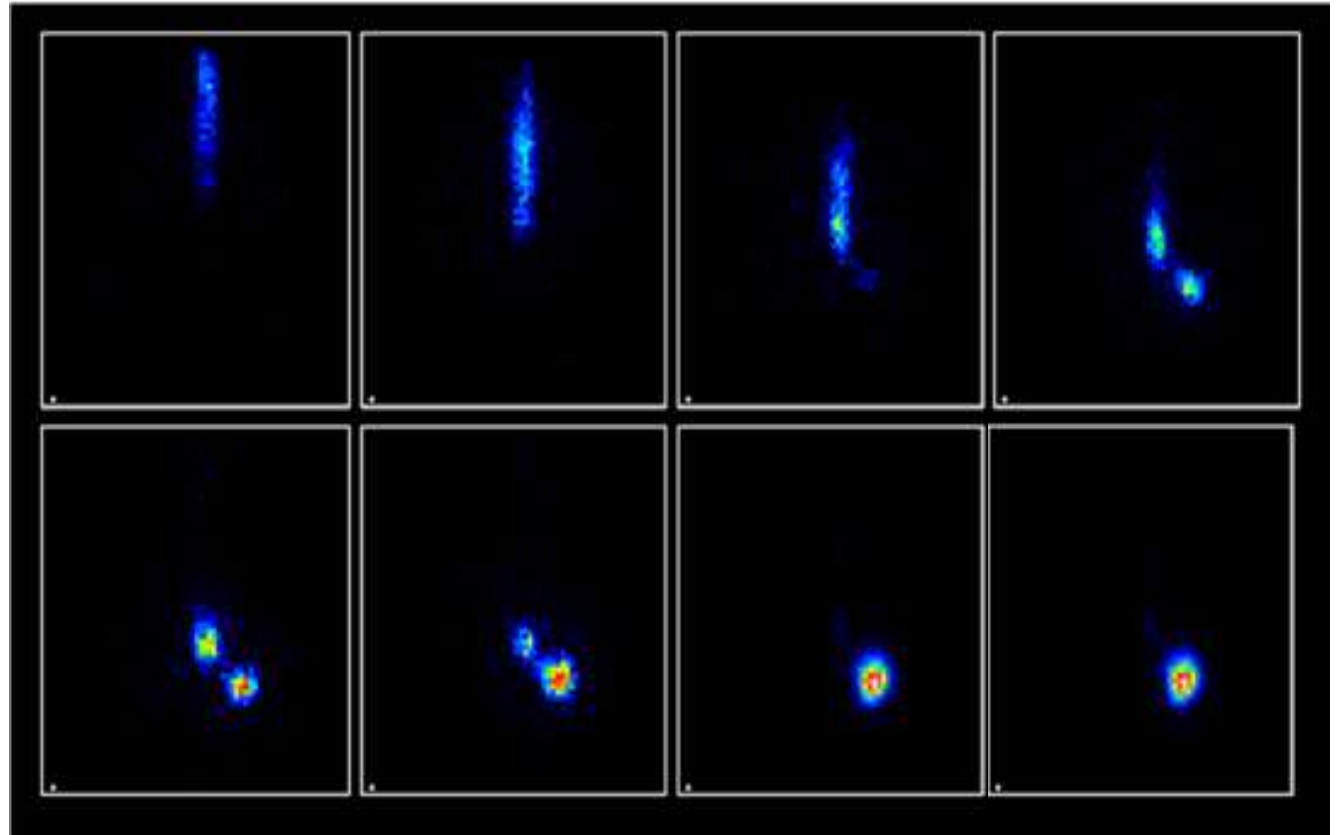


# THE TRANSIT TEST

## Qualitatively analysis

Normal scan:

The bolus traverses the oesophagus in a single wave of peristalsis in 8-10 s or so, with no delay, no fragmentation of the bolus, and no reflux

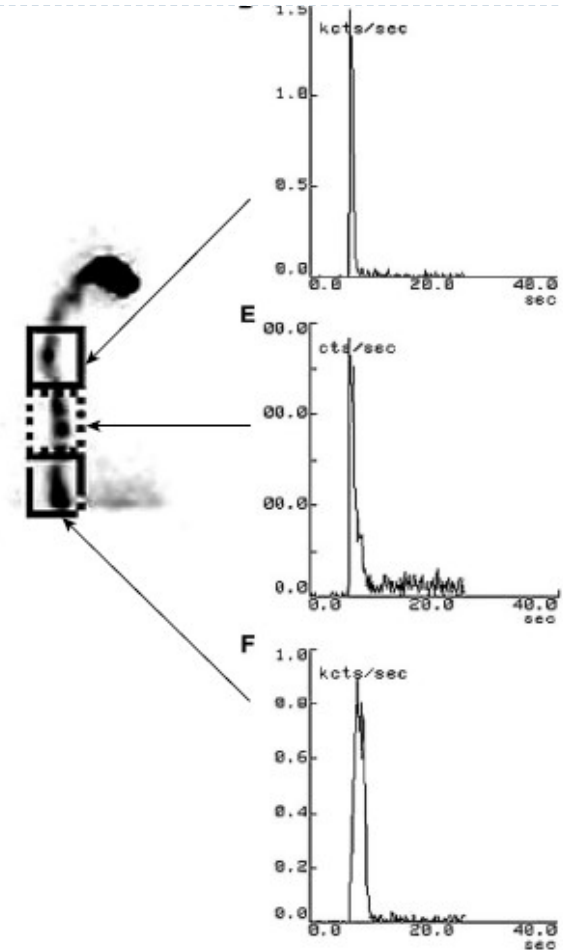


# THE TRANSIT TEST

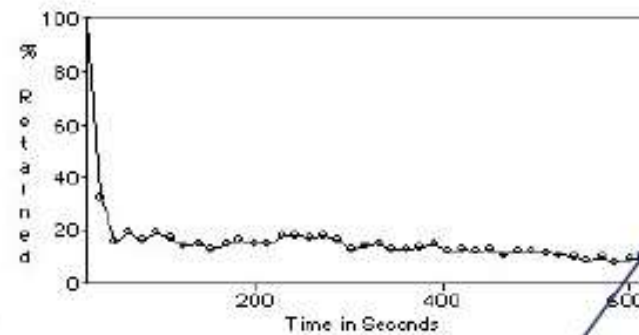
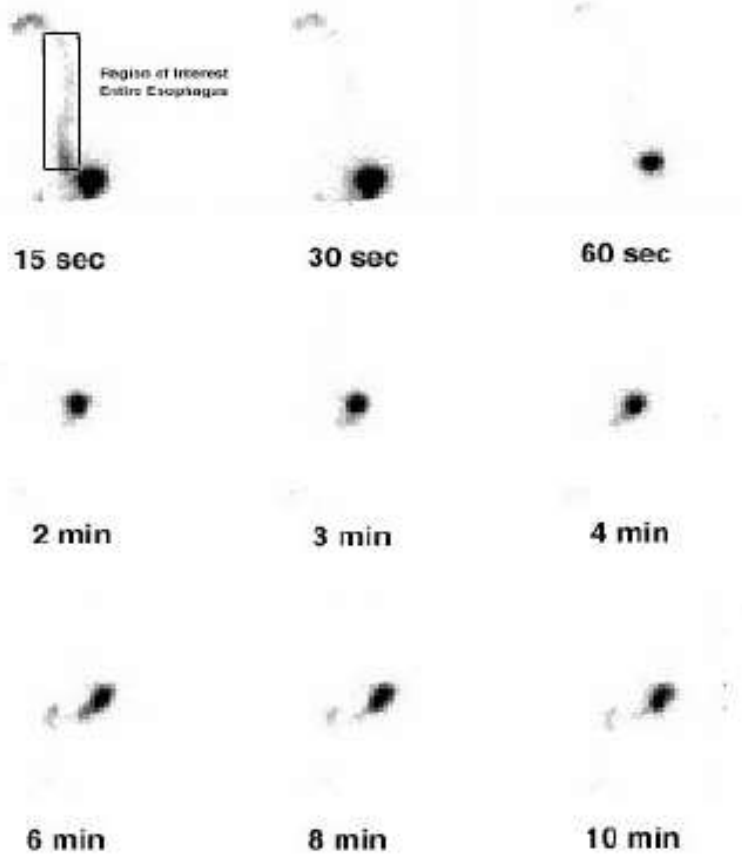
Transit through the upper third of the oesophagus usually takes about 1 s, through the middle third about 2 s, and through the lower third about 6 s, giving a transit time through the whole oesophagus of 8-10 s.

$$E_t (\%) = \frac{cts_{\max} - cts_{\sec}}{cts_{\max} - cts_{\text{res}}} \times 100$$

$cts_{\text{res}}$  – residual activity



# THE TRANSIT TEST



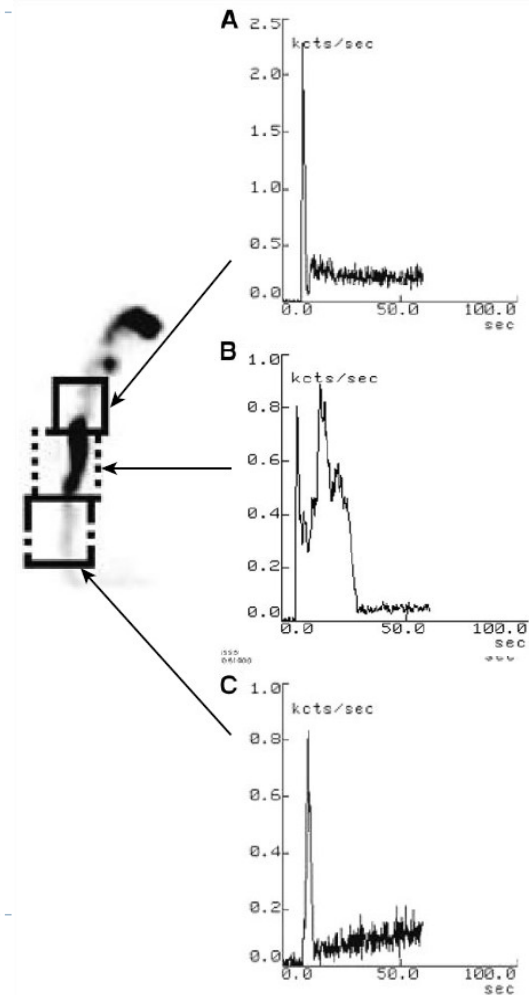
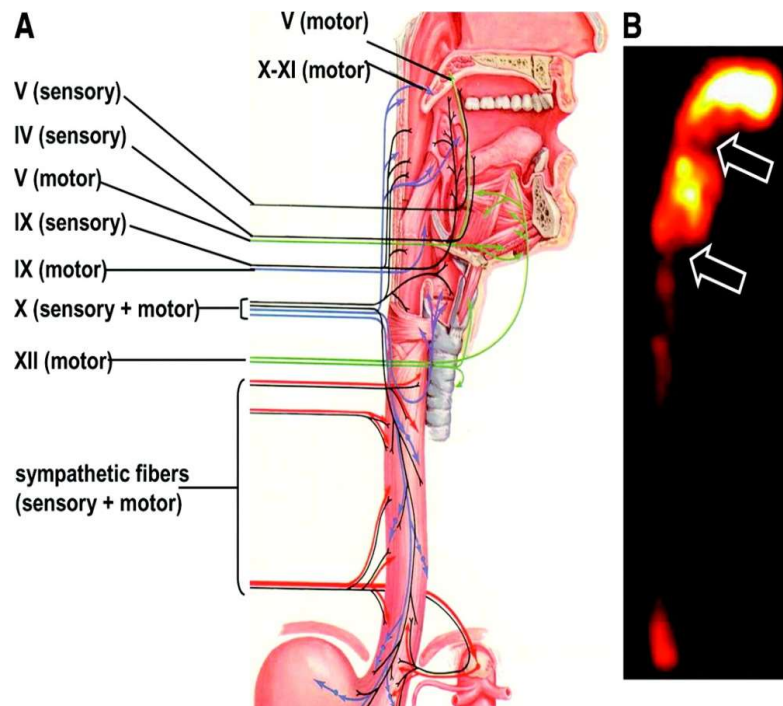
Normal transit time  
 $\leq 15$ s.

“washout”  $\geq 80\%$

Normal  $< 18\%$  at 10 min

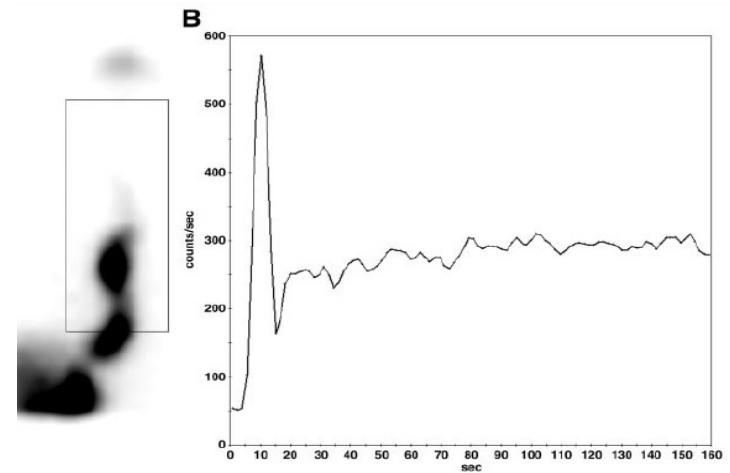
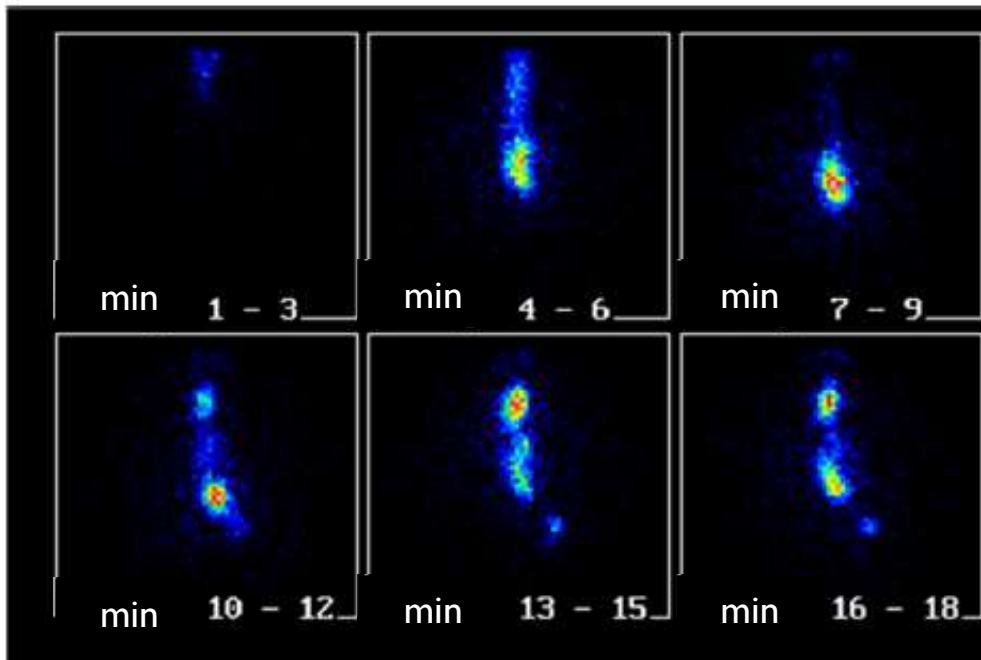
# THE TRANSIT TEST

Diffuse esophageal spasm (DES):



# THE TRANSIT TEST

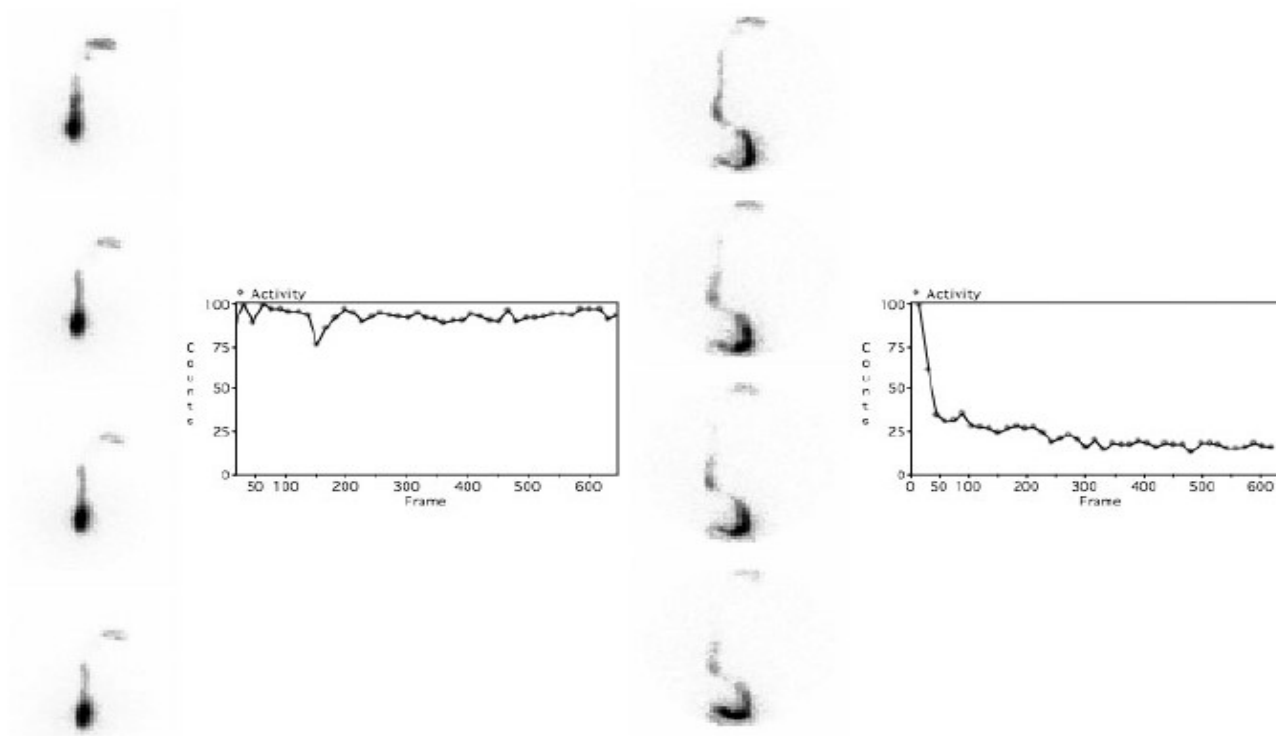
- ▶ Achalasia (failure to relax)
- ▶ Scleroderma esophagus



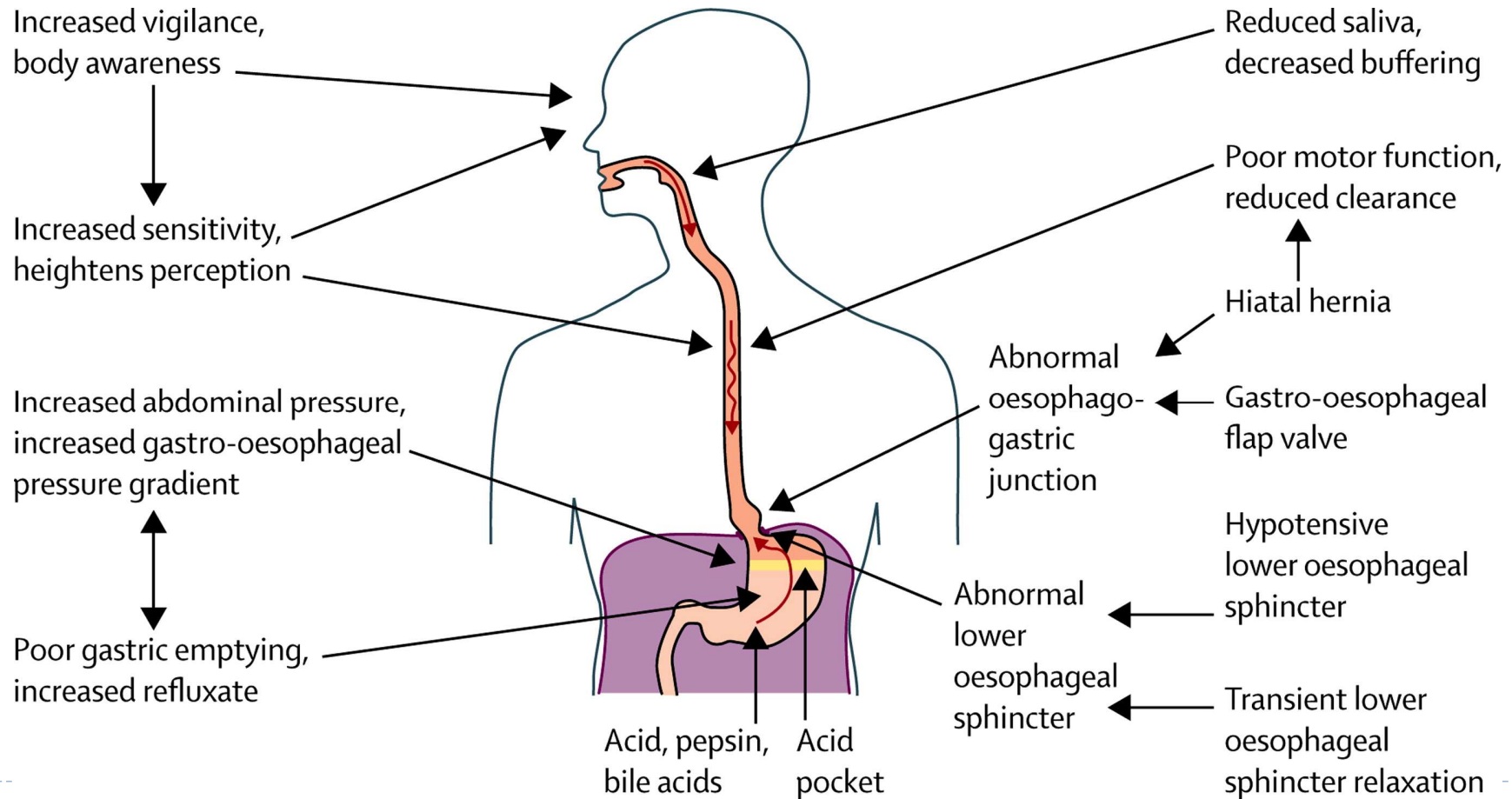
# THE TRANSIT TEST

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- ▶ Achalasia (failure to relax): before and after treatment



# Gastroesophageal Reflux Disease





# Gastroesophageal Reflux Disease

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- ▶ The pathogenesis of gastroesophageal reflux disease (GERD) is complex and involves changes in reflux exposure, epithelial resistance, and visceral sensitivity.
- ▶ The gastric refluxate is a noxious material that injures the esophagus and elicits symptoms. Esophageal exposure to gastric refluxate is the primary determinant of disease severity. This exposure arises via compromise of the anti-reflux barrier and reduced ability of the esophagus to clear and buffer the refluxate, leading to reflux disease.
- ▶ Complications and symptoms also occur in the context of normal reflux burden, when there is either poor epithelial resistance or increased visceral sensitivity. Reflux therefore develops via alterations in the balance of aggressive and defensive forces.



# Symptoms of GERD

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- ▶ Symptoms related to complications of GERD
  - ▶ Dysphagia and odynophagia
    - ▶ Associated with mechanical or functional obstructions that may cause reflux damage
  - ▶ Hematemesis and melena
    - ▶ Rarer complications
    - ▶ Related to bleeding esophagitis,
    - ▶ Indicate extensive mucosal damage and suggest the possibility of columnar-lined mucosa



## Diagnostic Tests

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- ▶ Empiric Trial of Acid Suppression
- ▶ Endoscopy
- ▶ Esophageal Biopsy
- ▶ Esophageal pH Monitoring
- ▶ Barium Esophagram
- ▶ Esophageal Manometry



## GERD scan

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- ▶ Patients fasted for 6 hours prior to the test.
- ▶ A dose of 60-70 MBq of  $^{99m}\text{Tc}$  S-colloid was administered in 50 mL of water followed by a further 50 mL of water to clear the oropharynx and esophagus.
- ▶ Dynamic images acquired upright for 2 minutes

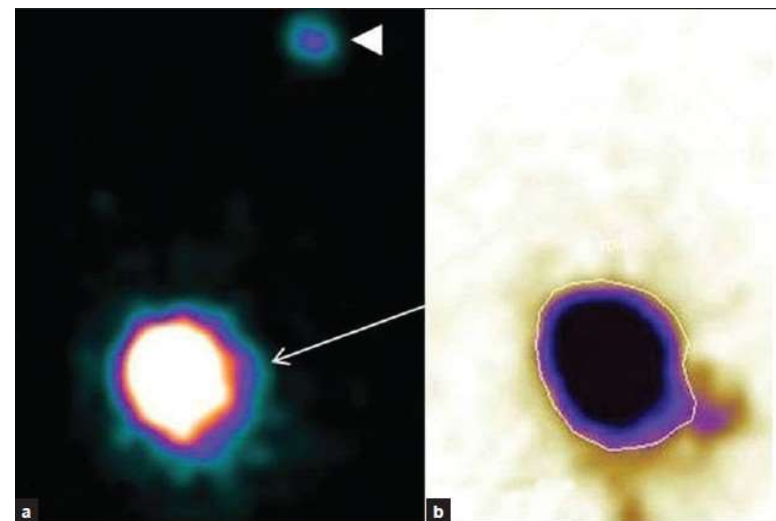
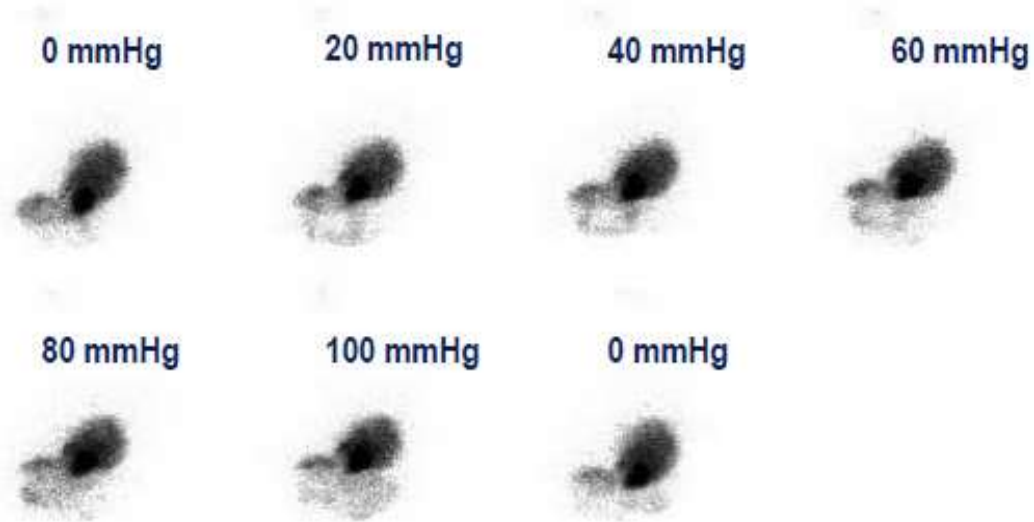
### “Milk scan”

- ▶ 100 ml milk/ $^{99m}\text{Tc}$ -S-colloid
- ▶ 1s/frame for 4min

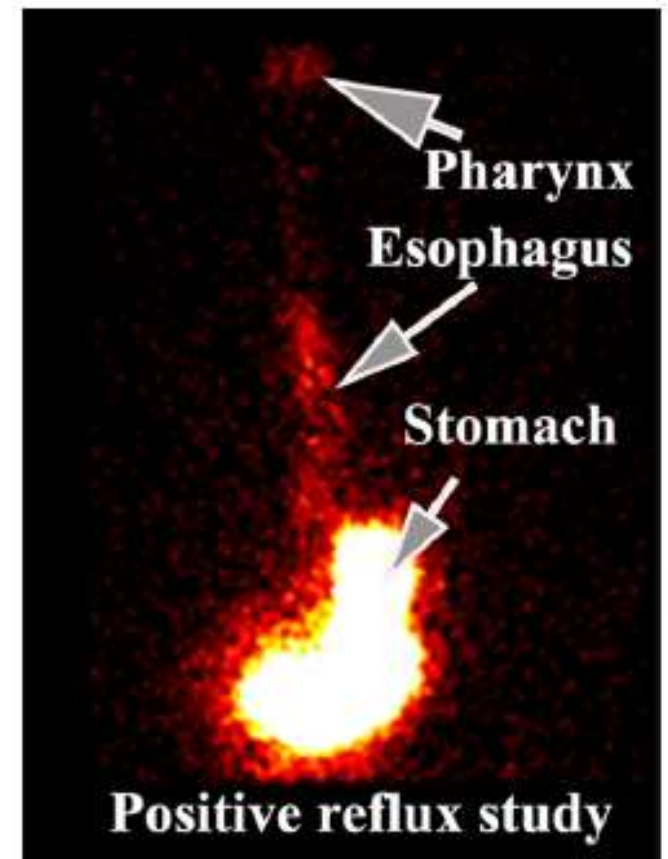
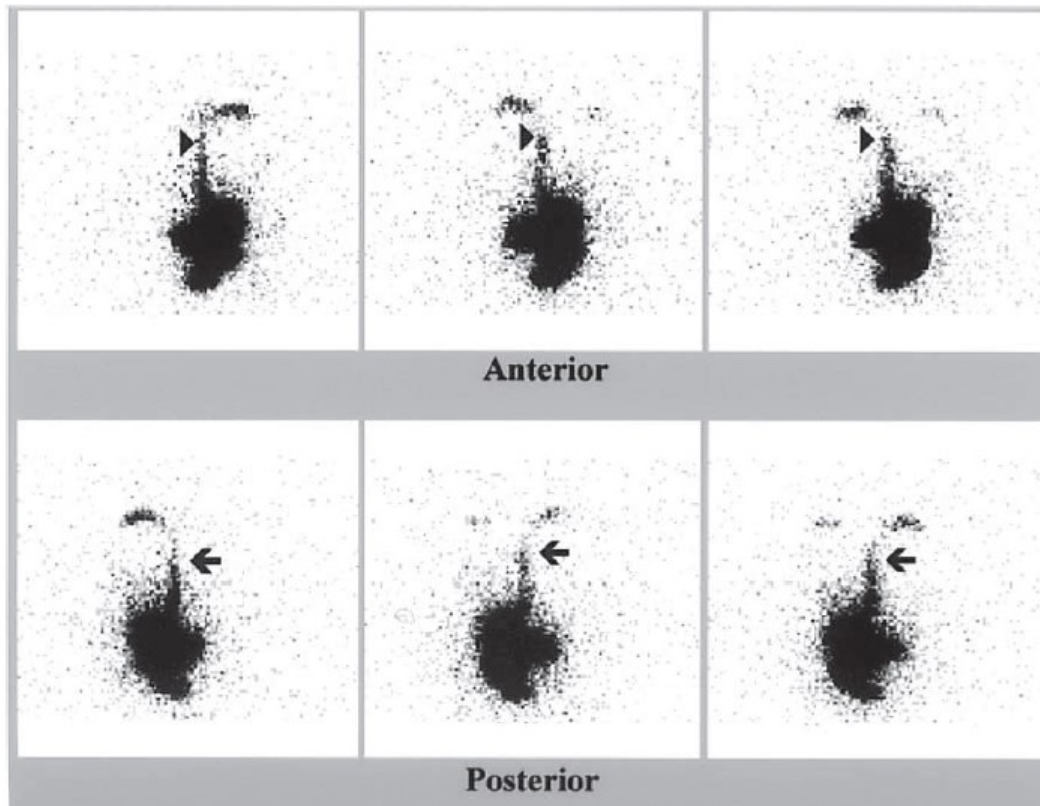


# GERD scan

## ► Normal scan



# GERD scan



# GERD scan

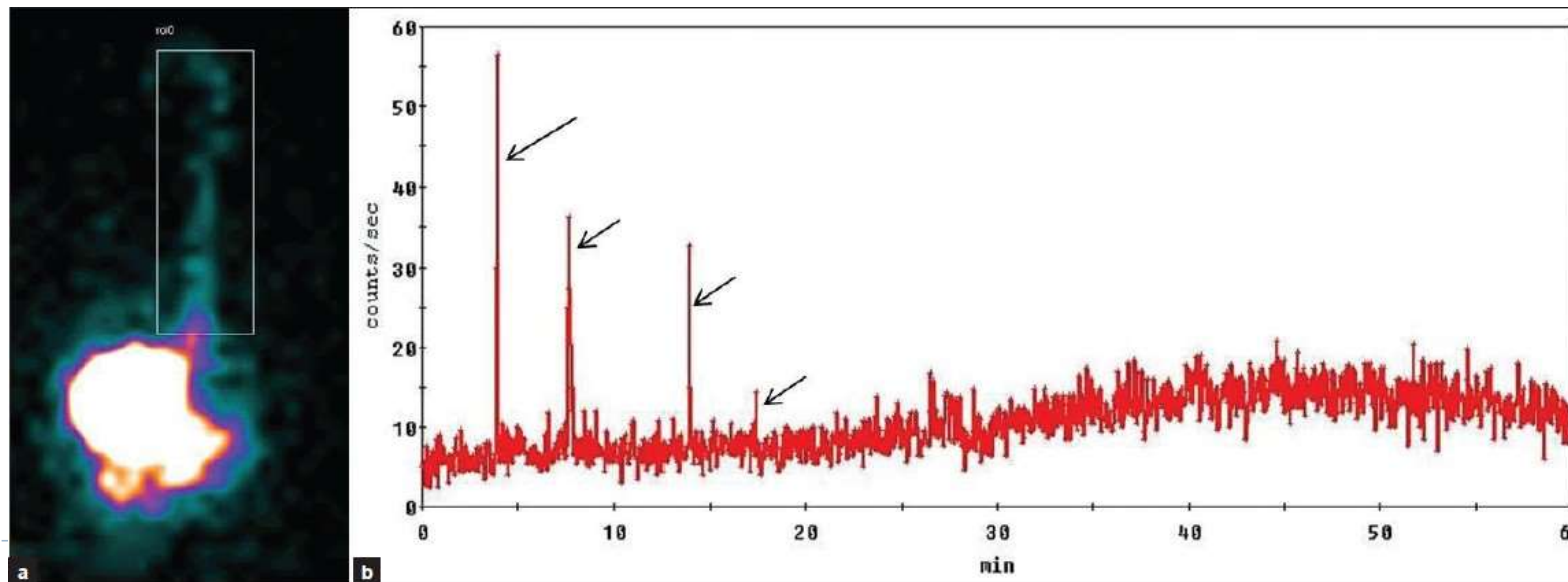
## Quantitative analysis

►  $R = \frac{E - E_{bg}}{G_0} \times 100$

Normal – up to 3%

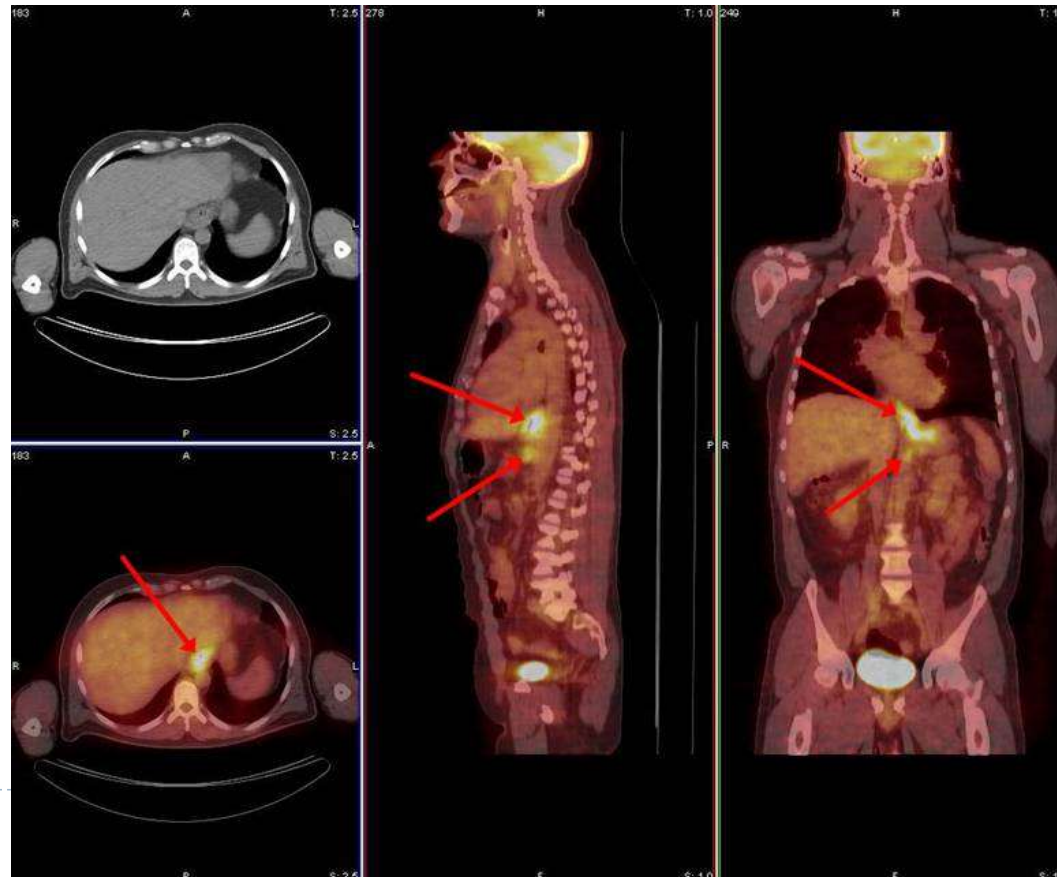
Border line – 3-4%

Pathological  $\geq 4\%$



# $^{18}\text{F}$ -FDG PET/CT

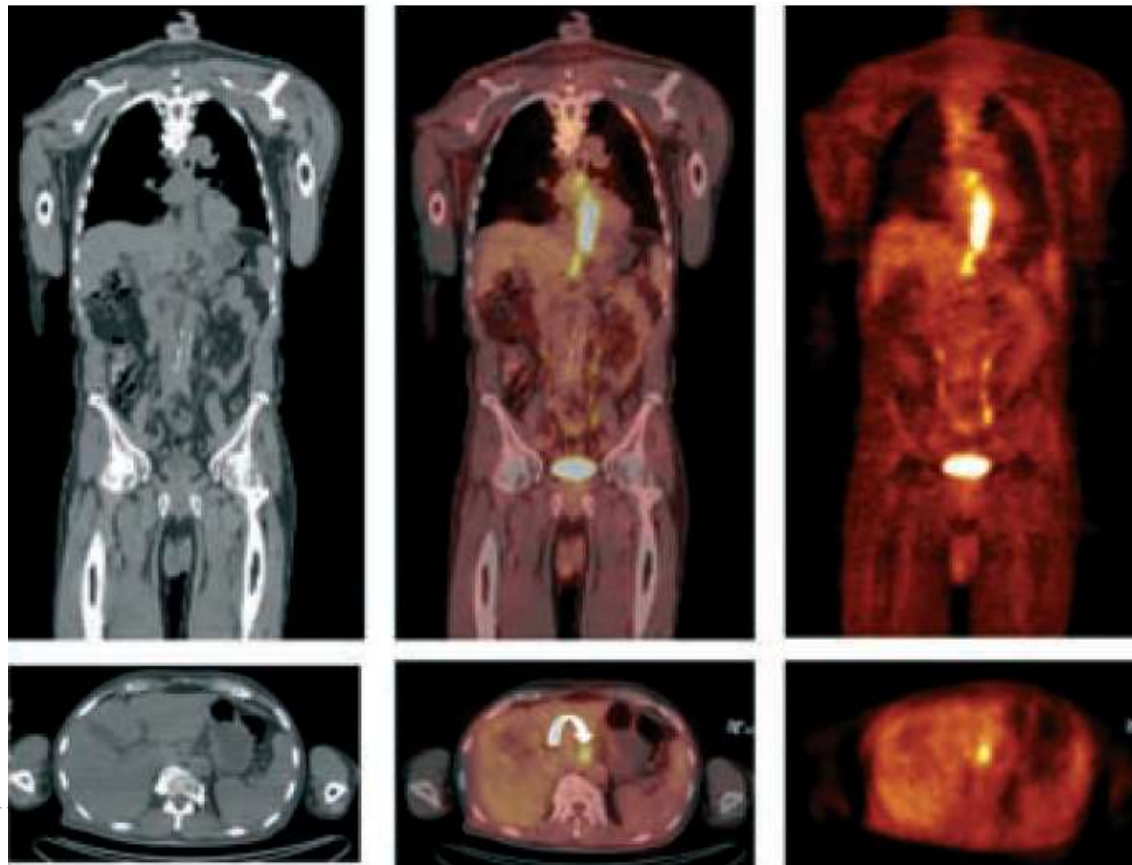
## Oesophageal cancer





# $^{18}\text{F}$ -FDG PET/CT

## Oesophageal cancer



# Gastric Emptying Scan

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- ▶ Solid:  $^{99m}\text{Tc}$  Sulfur Colloid or  $^{99m}\text{Tc}$  Albumin Colloid
- ▶ Liquid:  $^{99m}\text{Tc}$ -DTPA
- ▶ Radiotracers are mixed with solid food and liquid; administered orally
- ▶ The Radiotracers are moved along with food through GI tract; the radiotracers attached allows for images to be taken while food being processed



## Imaging Protocols

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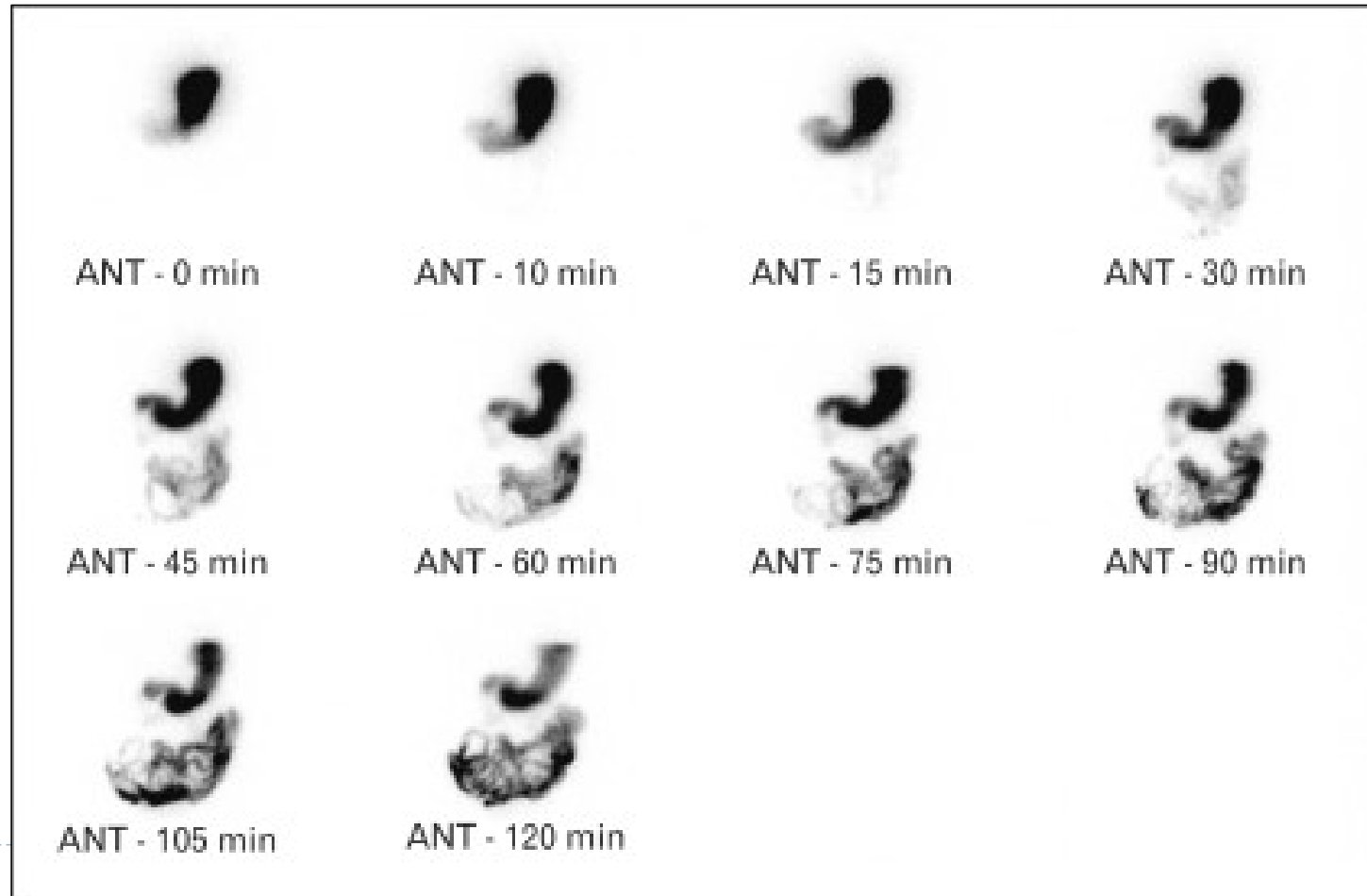
- ▶  $^{99m}\text{Tc}$  Sulfur Colloid
- ▶ Supine position with stomach in FOV
- ▶ Images are acquired immediately
- ▶ Dynamic images at 30-60 sec/frame for at least 90 min
- ▶ Static images can be acquired at 15 min intervals



# Gastric Emptying Scan

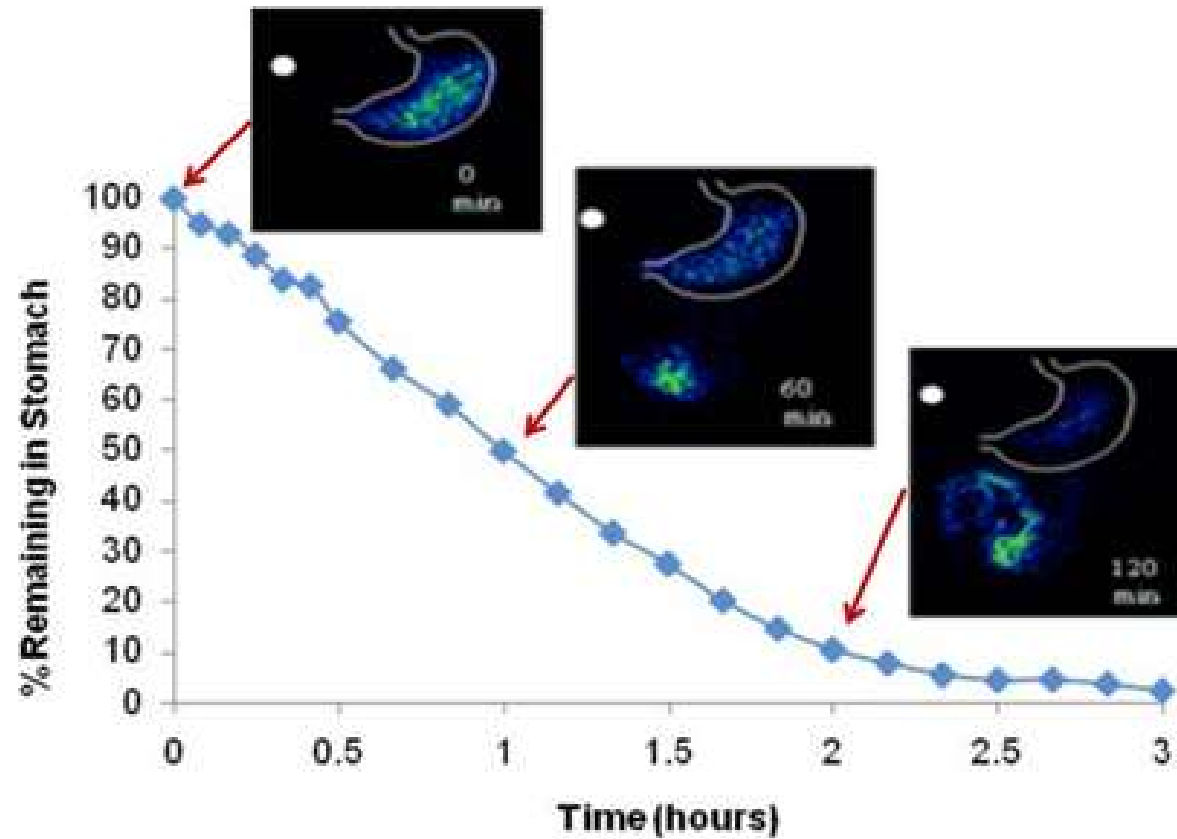
Delayed	Rapid
Diabetic gastroenteropathy	Diabetic gastroenteropathy
Non-ulcer dyspepsia	Pyloroplasty, hemigastrectomy
Hypothyroidism	Hyperthyroidism
Gastric ulcer	Zollinger-Ellison syndrome
Pernicious anemia	(gastrinoma)
Amyloidosis	
Connective tissue disorders (e.g., SLE)	
Post-vagotomy	
Tumor-associated gastroparesis	
Myotonic dystrophy	
Familial dysautonomia	
Hyperglycemia	
Uremia	
Hypercalcemia	
Gastroenteritis	

## Gastric Emptying Scan



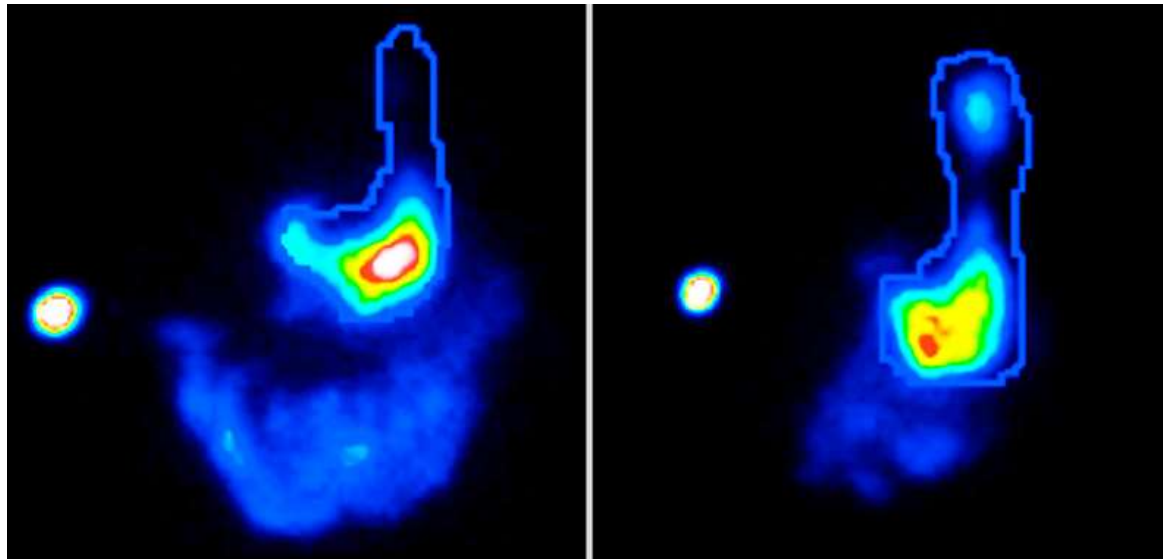
# Gastric Emptying Scan

Normal findings



# Gastric Emptying Scan

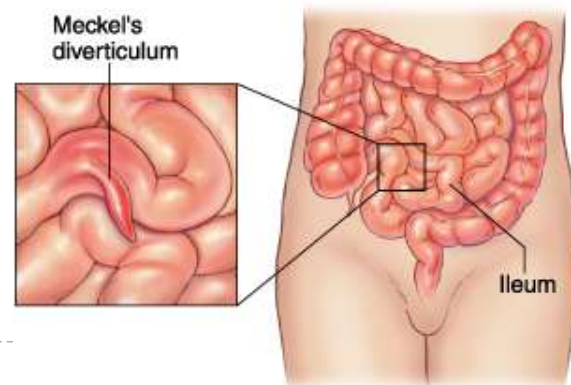
- ▶ Pathological findings



- ▶ **Grade 1:** 11-20% retention up to 4h
- ▶ **Grade 2:** 21-35% retention up to 4h
- ▶ **Grade 3:** 36-50% retention up to 4h
- ▶ **Grade 4:** >50% retention up to 4h

# Meckel's Diverticulum

- ▶ Meckel's diverticulum is an outpouching or bulge in the lower part of the small intestine. It is the most common congenital defect of the gastrointestinal tract. It occurs in about 2% to 3% of the general population.
- ▶ Meckel's diverticulum occurs in a fetus early in the pregnancy. Normally, the vitelline duct, which connects the growing fetus with the yolk sac, is absorbed into the fetus by the seventh week of the pregnancy. When the vitelline duct is not fully absorbed, a Meckel's diverticulum develops.
- ▶ A Meckel's diverticulum may contain cells from both the stomach and pancreas.
- ▶ Cells from the stomach can secrete acid, which can cause ulcers and bleeding.





# Meckel's Diverticulum

---

Meckel's diverticulum is described by the "Rule of Twos," which states:

- ✓ It occurs in 2% of the population.
- ✓ The symptoms usually appear before the age of two or within the first two decades of life.
- ✓ There are two types of ectopic tissue (gastric and pancreatic).
- ✓ It is usually located within 2 ft of the small and large intestine junction (ileocecal valve).
- ✓ It is approximately 2 in (5 cm) long.
- ✓ It is two times more likely to be symptomatic in males than females, and
- ✓ 2% become symptomatic (however, most Meckel's diverticula are clinically silent).



# Meckel's Diverticulum scan

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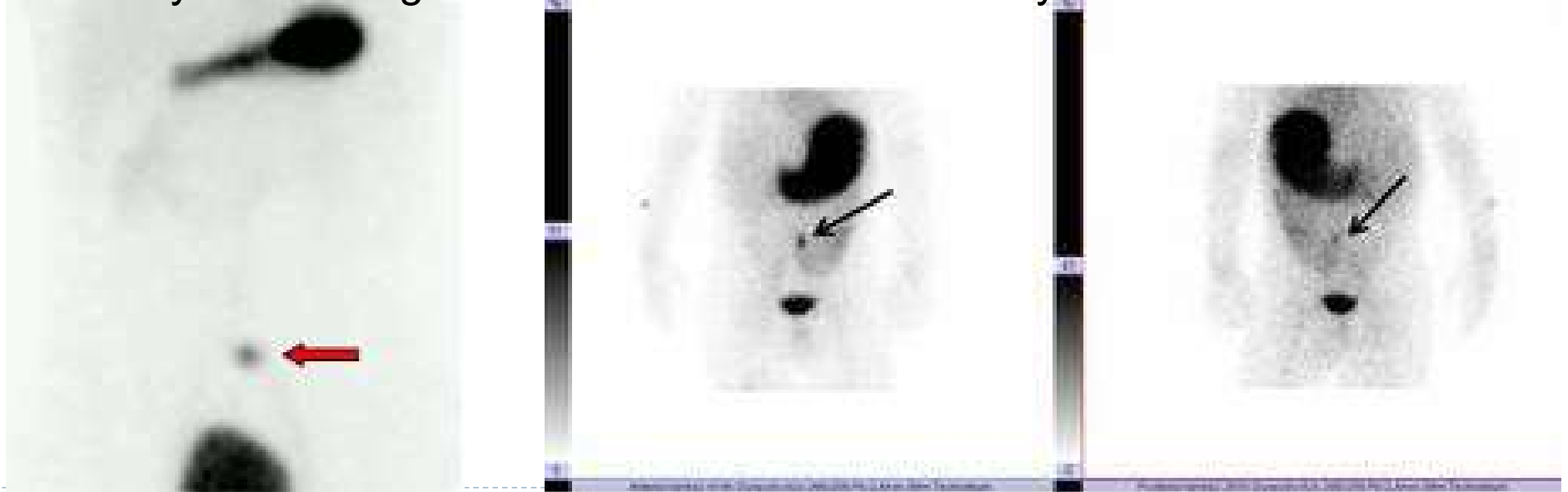
## Before scan

- ▶ Do not perform barium tests a few days before the study
- ▶ Pentagastrin 6 mg/kg stimulates the accumulation of pertechnetate in the gastric mucosa by 30-60% with a decrease in emptying time into the small intestine and basal activity. It is administered intramuscularly in children, subcutaneously in children. It is given 15 min before the injection of  $^{99m}\text{TcO}_4$ ,
- ▶ Glucagon 50 $\mu\text{g}$  reduces peristalsis and increases retention of activity in ectopic mucosa
- ▶ Cimetidine 300mg reduces the release of pertechnetate from the ectopic mucosa into the intestinal lumen and increases accumulation in the stomach



## Детекција хетеротопичне желудачне слузнице

Meckel's diverticulum scan is based on accumulation of technetium-99m ( $^{99m}\text{Tc}$ ) pertechnetate in the gastric mucosa. Pertechnetate concentrates in the gastric mucosa by active transport in the mucous cells. It is transported in a manner similar to that of halide anions (e.g., chloride and iodide). Pertechnetate can be excreted by either the gastrointestinal tract or the kidneys.



## **Lower gastrointestinal tract**

# Gastrointestinal Bleeding

- ▶ Radiopharmaceutical via compartment circulates in the blood
- ▶ *Active bleeding*( $^{99m}\text{Tc-S-Colloid}$ ): leaves blood pool by means of RE cells quickly
- ▶ Active bleeding should be visualized within 5 min
- ▶ *Intermittent bleeding*: tagged RBC's remain in the blood longer ; allows for delayed imaging

Radiotracer administered intravenously or drawing, tagging and reinjection of tagged RBC's In-vivo or In-vitro

<i>Tc-99m RBC</i>	<i>Tc-99m SC</i>
<ul style="list-style-type: none"><li>❖ Bleeding 500+ ml/ 24 hr.</li><li>❖ Bleeding rate 0.1-0.5 ml/min</li><li>❖ Intermittent bleeding- 24h F/U wo reinjection</li><li>❖ Lower T/B ratio (higher Bcg)</li><li>❖ Upper &amp; lower GI bleeding</li></ul>	<ul style="list-style-type: none"><li>❖ T1/2 in bl pool 2.5-3 min</li><li>❖ Bleeding rate 0.05-0.1 ml/min*</li><li>❖ Intermittent bleeding requires reinjection</li><li>❖ Higher T/B ratio (lower Bcg)</li><li>❖ Upper abd interfered by liver-spleen activity</li></ul>

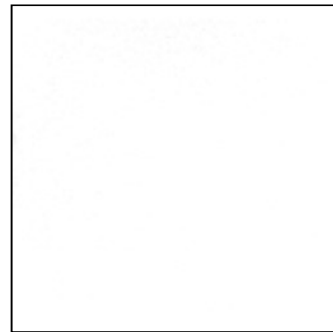
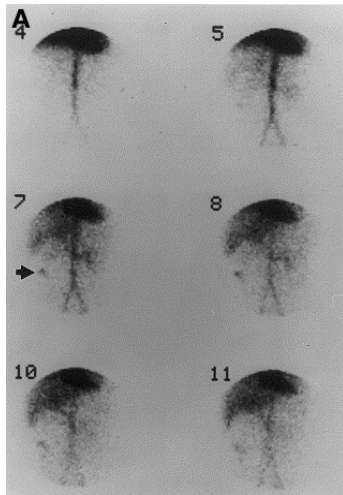
# Imaging Protocols

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- ▶ Supine position with abdomen in FOV
- ▶ Rapid sequential images acquired as tracer is administered (active bleeding)
- ▶ Dynamic imaging acquired for 60 min after flow
- ▶ Static imaging acquired anteriorly at intervals of 5 min for up to 60-90 min with RAO and LAO
- ▶ If patient has a bowel movement imaging of feces for signs of active bleeding

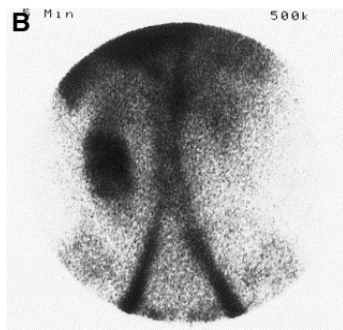


# Gastrointestinal Bleeding



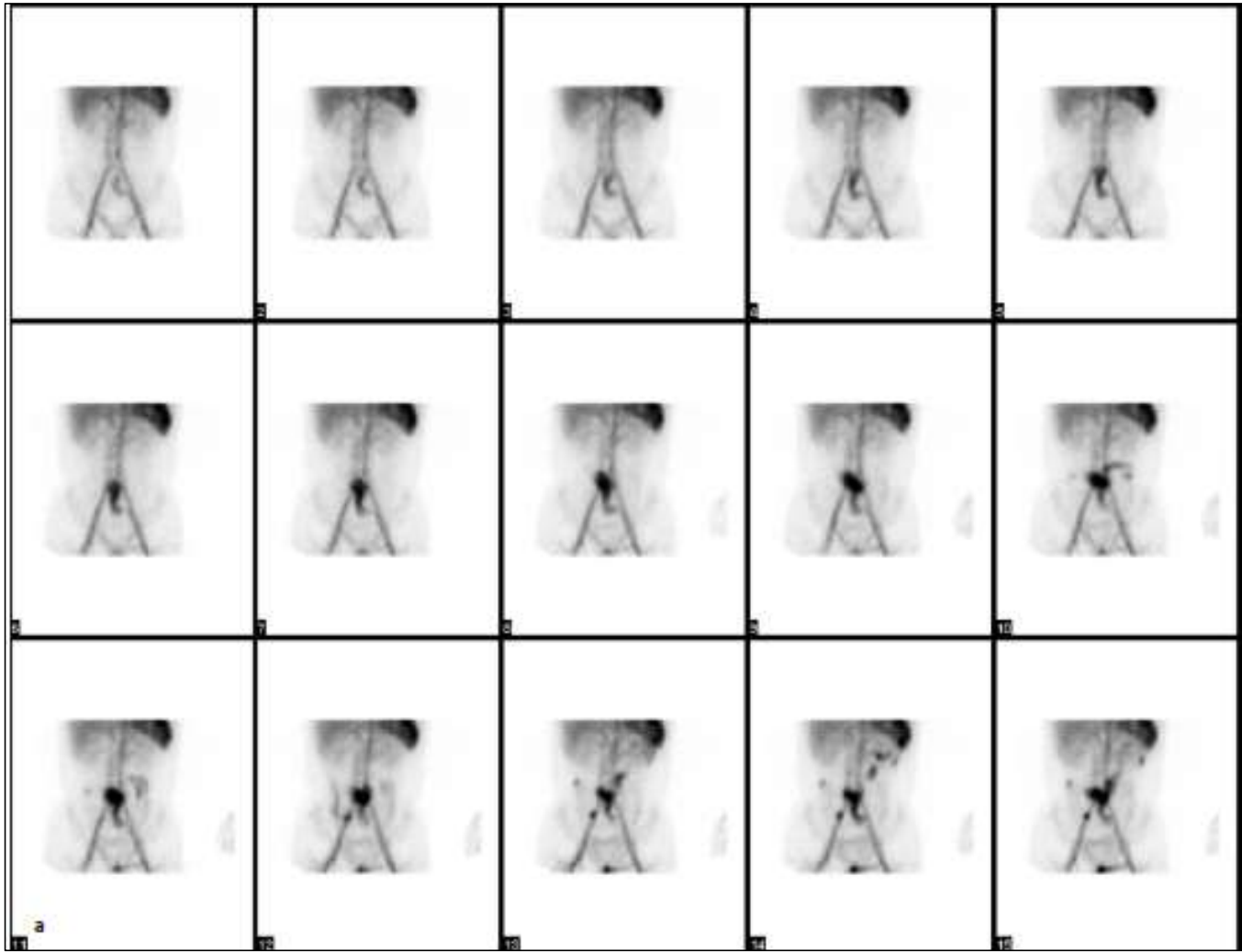
0-30min

- Early sequences (0-30 min.)  
Activity is normally seen in the region of the aorta and iliac arteries.

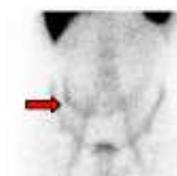
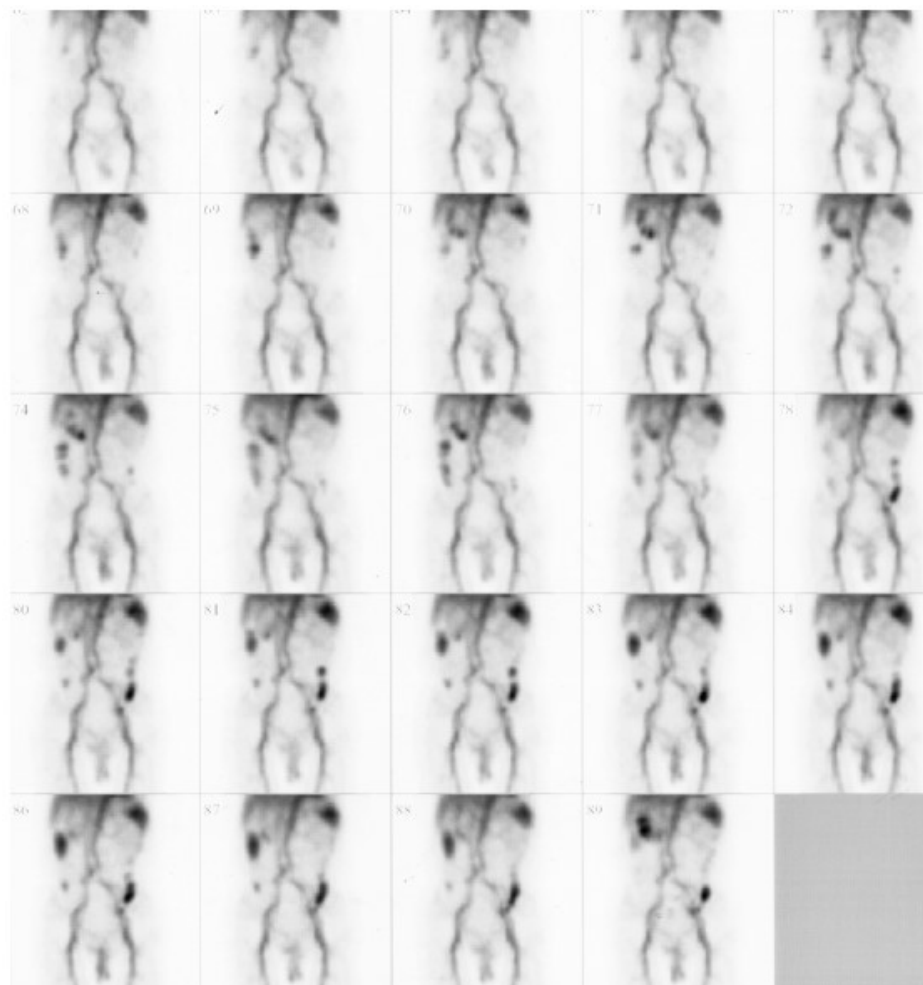


30-60min

- Later sequences (up to 60 min.)  
show the site of increased accumulation at the level of the cecum, and later the colon.







ANTERIOR 1HR

POSTERIOR 1HR

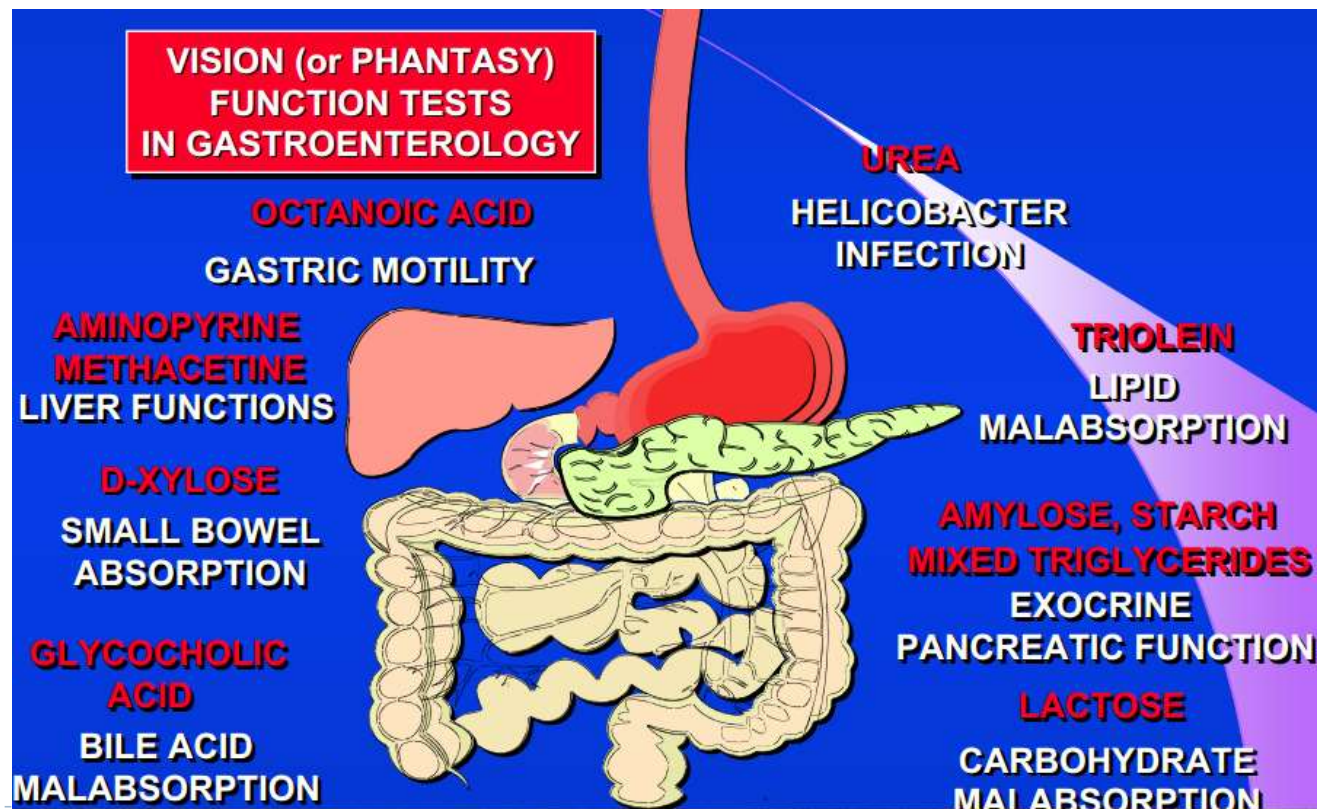


ANTERIOR 3HR

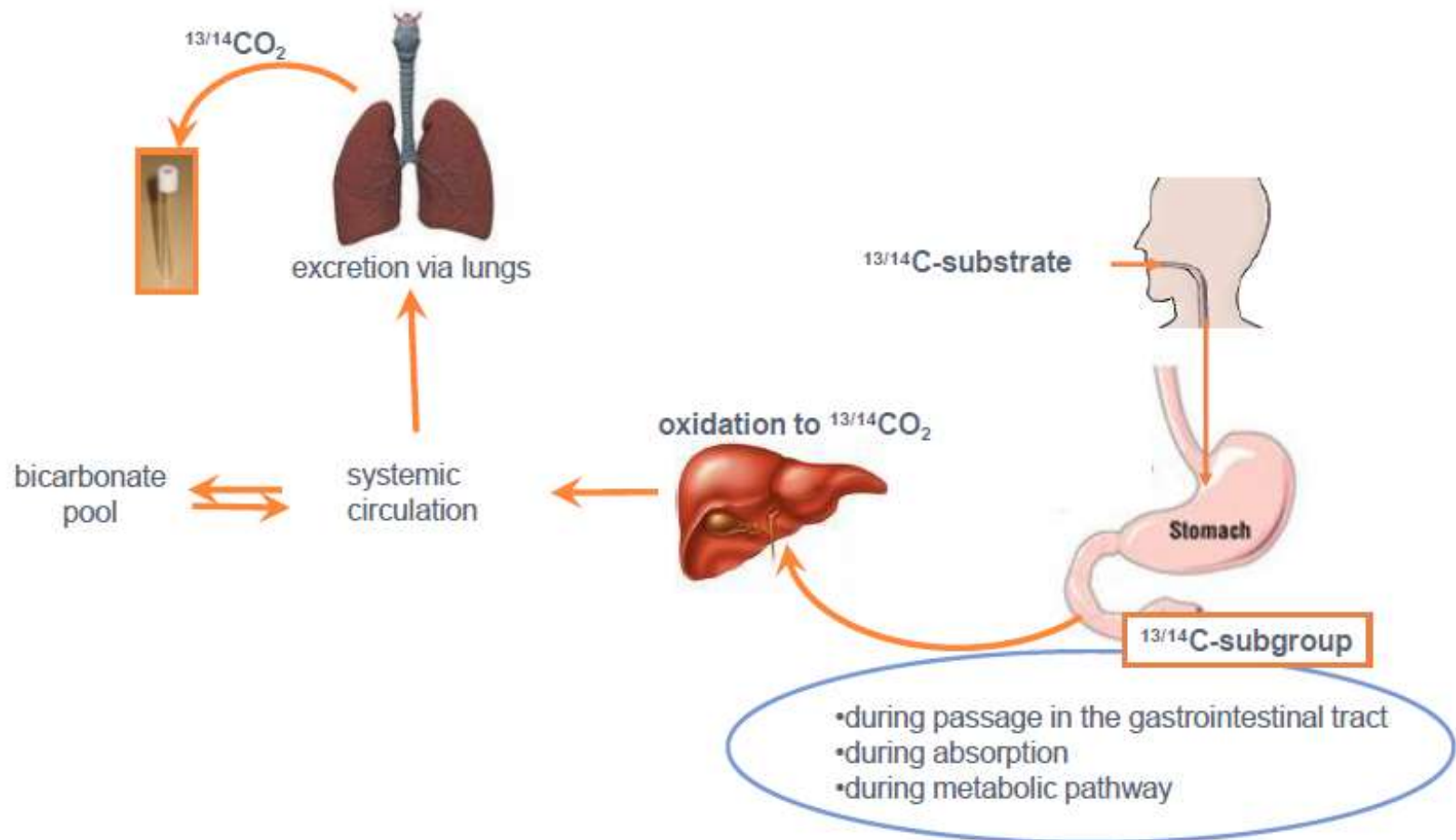
POSTERIOR 3HR

# Breath tests in routine clinical diagnose

- ▶  $^{14}\text{CO}_2$  in exhale air 9mmol/kg/h



# Principle of $^{13}\text{C}/^{14}\text{C}$ -breath tests



# $^{14}\text{C}$ or $^{13}\text{C}$ ?

## $^{14}\text{C}$

radiation dose:  $e_{50} = 0,043 \text{ mSv/74 kBq}$   
(ICRP-68, 1994,  $f = 1$ ,  $t_{1/2} \text{ biol} = 28\text{d}$ )  
not in children (-18y) nor in pregnant women

$t_{1/2} \text{ }^{14}\text{C}$ : 5730 y  $\Rightarrow$  radiation burden for the environment

$\beta$ -scintillation

simultaneous measurement of gastric emptying  
with solid and fluid test meal  
glycocholic acid breath test

## $^{13}\text{C}$

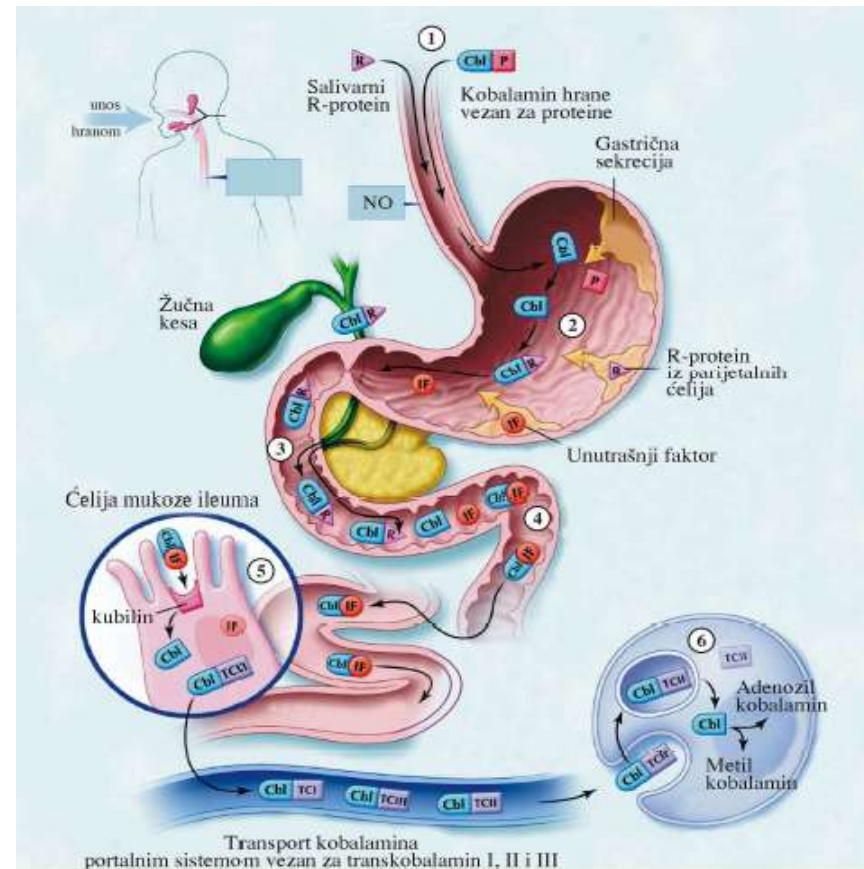
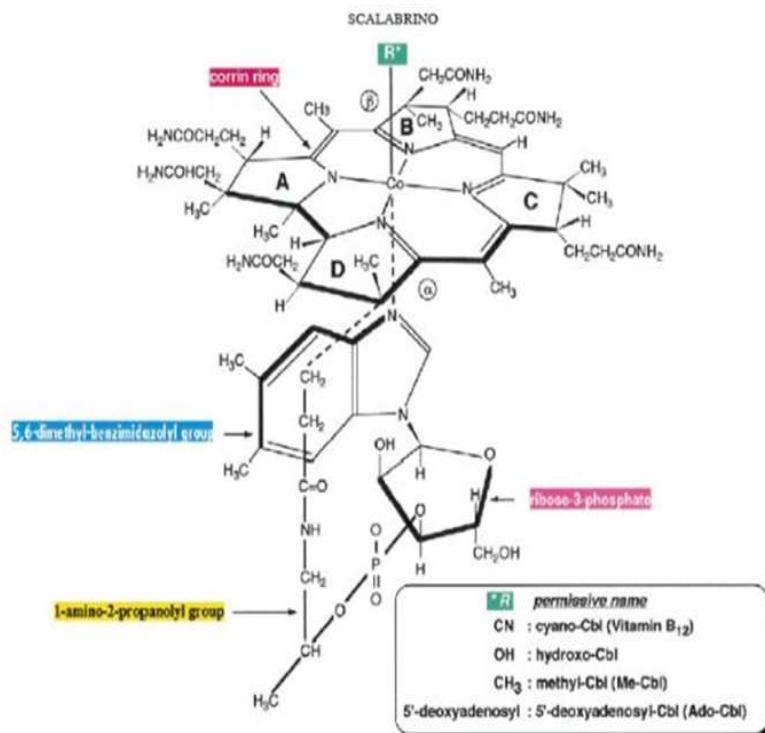
no radiation dose  
safe in children and pregnant women  
can be repeated several times

possible interference from naturally  
enriched compounds e.g. glucose (TPN  
and glucose infusions)

isotope ratio mass spectrometry

all other breath tests

# Vitamine B<sub>12</sub>





# Vitamine B<sub>12</sub>

## Schillings test

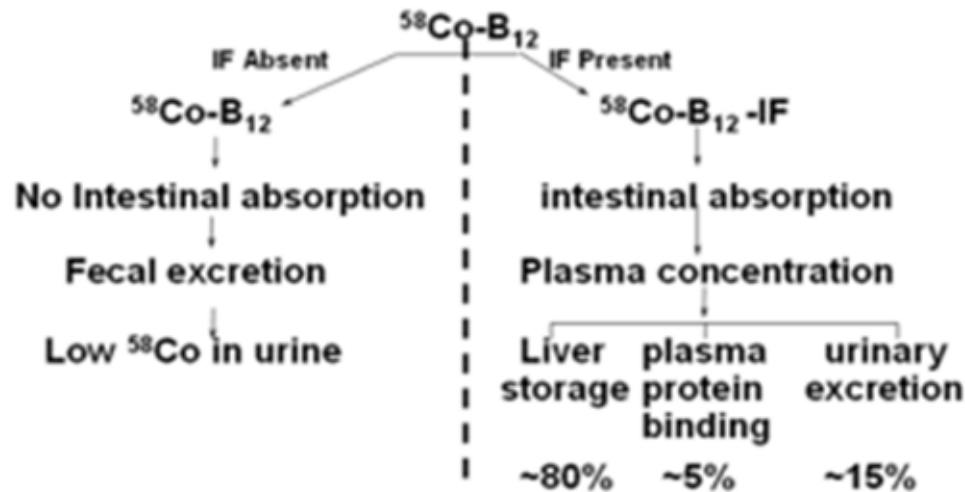
- ▶  $^{57}\text{Co}$  ili  $^{58}\text{Co}$  vitamin-B<sub>12</sub> -
- ▶  $^{57}\text{Co-B}_{12}$  +  $^{58}\text{Co}$ -intrinsic factor B<sub>12</sub>

## Normal findings 24h

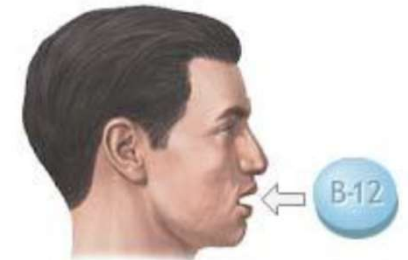
$^{58}\text{Co}$ =12-30%

$^{57}\text{Co}$ =11-28%

$^{58}\text{Co}:^{57}\text{Co}\sim 1$



Injection of nonradioactive vitamin B12 given



Radioactive B12 ingested



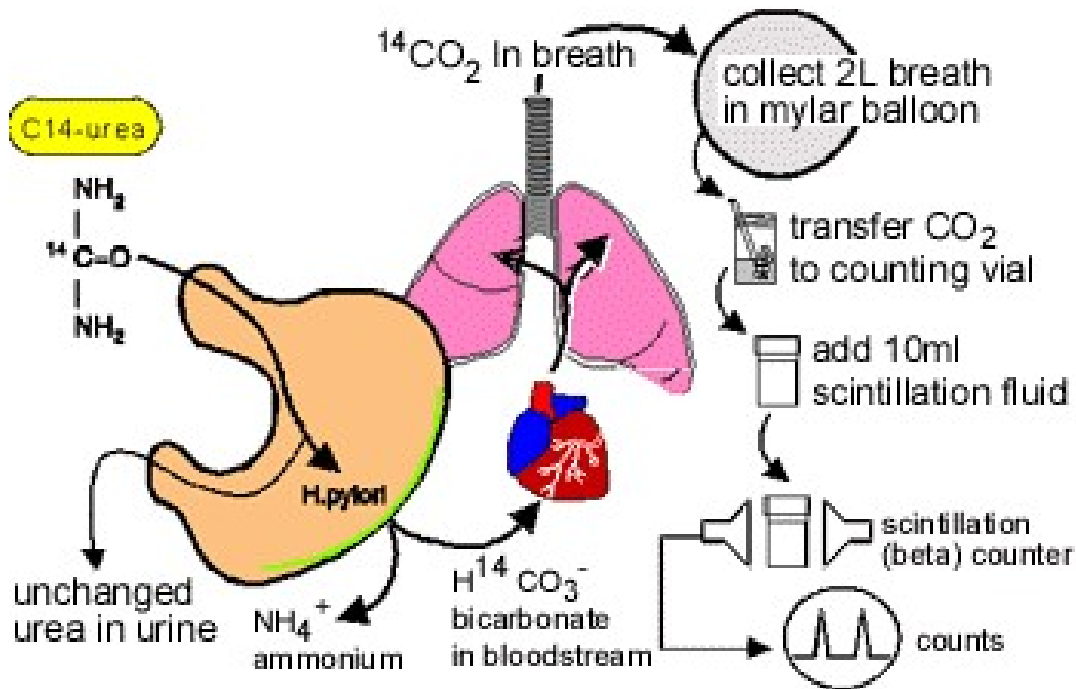
Urine samples are collected

ADAM.

# Helicobacter pylori infection

## $^{14}\text{C}$ -urea

- ▶  $\text{H}_2\text{N}(^{14}\text{CO}_2)\text{NH}_2\text{O} + \text{H}_2\text{O} \xrightarrow{\text{urease enzyme}} 2\text{NH}_3 + ^{14}\text{CO}_2$
- ▶  $^{14}\text{C}$ -converts in  $\text{CO}_2$  и  $\text{NH}_3$  urease-producing bacteria



## CO<sub>2</sub> breath tests

### Triolein Breath Test

The <sup>14</sup>C-triolein breath test was evaluated as a screening test for fat malabsorption .

After the ingestion of a 30-g fat meal containing <sup>14</sup>C-triolein, the breath excretion of <sup>14</sup>CO<sub>2</sub> was measured at hourly intervals for 6 h and compared with a 3-day faecal excretion of fat.

- ▶ > 3,4%/h у издисајном ваздуху
- ▶ Pancreas insufficiency <1,5%/h
- ▶ Celiac disease <0,5%/h

### <sup>14</sup>C Lactose

suspicion of osmotic diarrhoea on the basis of lactose-malabsorption  
– complaints are usually flatus, ructus, postprandial cramps, bloating

normal value

- peak excretion > 6.5%
- cum%4h > 14.5%
- H<sub>2</sub>-excretion: (max. value – value t<sub>0</sub>) < 20 ppm



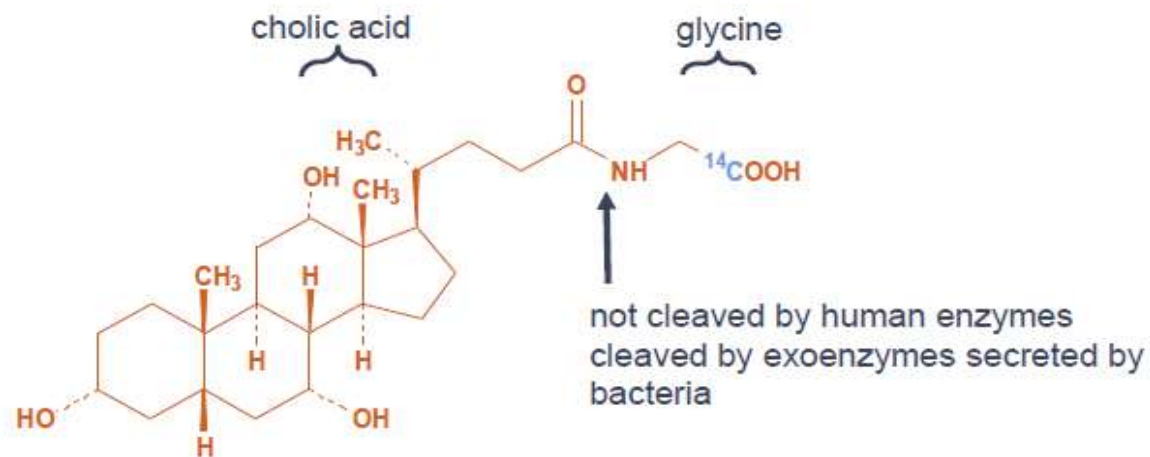
# $^{14}\text{C}$ -glycocholic acid

- **indication**

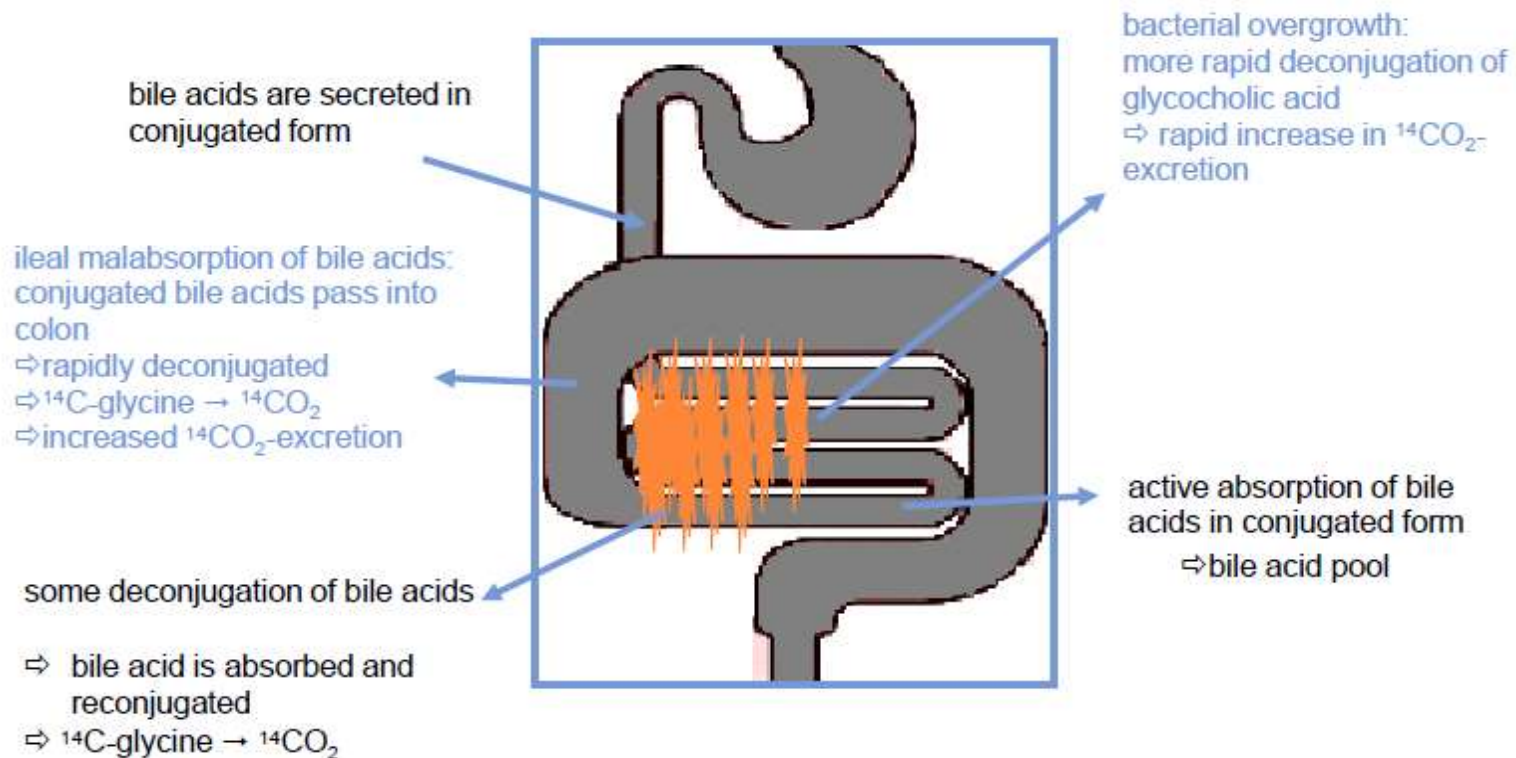
- diagnosis of bacterial overgrowth and/or ileal malabsorption

- **Principle**

- substrate:  $^{14}\text{C}$ -glycocholic acid = conjugated bile acid



# $^{14}\text{C}$ -glycocholic acid



# $^{14}\text{C}$ -glycocholic acid

## ► Practical

- test meal: substrate in gelatin capsule, taken with normal breakfast
  - breath samples: every 30 min
  - total test duration: 6h
- ## ► normal value
- cum%6h < 3%
  - especially the moment at which  $^{14}\text{CO}_2$ -excretion increases is important in the differential diagnosis between bacterial overgrowth and ileal malabsorption

