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Edited podcast transcription:

Welcome everybody to my first episode, which is an overview of Technetium 99m. Technetium 99m has a half-life of six hours and an energy of 140 keV which is optimal for imaging with low-energy high-resolution collimators. The combination of the six-hour half-life and the 140 keV energy allows Technetium 99m to essentially provide the best images possible at the lowest dose. That is part of the reason Technetium 99m is so widely used for nuclear medicine imaging. Additionally, Technetium 99m has easy radiochemistry. So, Technetium 99m, provides a balance of the best image quality at the lowest dose, and easy ability to attach pharmaceuticals to the radioactive compound.

Board Exam Tips for Technetium 99m:

If a patient is breastfeeding, you need to wait four half-lives which is approximately 24 hours to resume breastfeeding.

Technetium 99m unbound to another pharmaceutical is called free Technetium. When you inject free Technetium into the body you get a few things on the images that are key signs that this could be a free Technetium scan. First is an extremely hot stomach. The second is salivary gland uptake. We can utilize the hot stomach principle to our advantage during a Meckel's diverticulum scan. Keep in mind on a Meckel's scan that you are trying to image presence of ectopic gastric mucosa within the Meckel's diverticulum. To increase the uptake of radiotracer within the diverticula you can give cimetidine or other H2 blockers. The mechanism on how this works is a little tricky, just remember that it works.

Additionally, free Technetium can be used for thyroid imaging. It is key to remember that Technetium is trapped within the thyroid but not organified. That means that Technetium will wash out faster than radioactive iodine that becomes organified.

Technetium 99m can also be bound to sulfur colloid. Technetium sulfur colloid is a jack of all trades when it comes to Technetium imaging. If you inject ultra-filtered sulfur colloid, which means that you filter out the large particles and are left with only very small particles under about 200 nanometers. This will then move within the lymphatics and that is what can be used for lymphoscintigraphy. Sometimes board exams require you to remember particle sizes. If you can, remember less than 200 nanometers for ultra-filtered sulfur colloid for lymphoscintigraphy imaging.

If you inject unfiltered (which means large and small particles together) then the particles will get phagocytosed into the reticuloendothelial system, allowing for a liver spleen scan.

One other thing to remember for lymphoscintigraphy you are injecting subdermally. For other things like a liver spleen scan, you are mostly using an intravenous injection.

Keep in mind that the term colloid shift comes from the sulfur colloid imaging manifestation wherein the spleen has as much activity as the liver which is not normal but does happen in liver failure. Hence, the term colloid shift.

A more advanced topic is that of pleural peritoneal shunt imaging wherein the Technetium sulfur colloid is injected directly into ascitic fluid within the abdomen and is then allowed to diffuse throughout the ascitic fluid. If you then see activity that shows up in the thorax, you know that there must be a shunt

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through the diaphragm and that is called a pleural peritoneal shunt. The key for that is you are looking for activity above the diaphragm. It may be unilateral. It may be bilateral. The key is that activity above the diaphragm after you inject ascitic fluid means there is a shunt. This imaging can be very useful if you're trying to figure out the source of a pleural effusion in a patient with liver failure.

Now what if you eat the Technetium 99M sulfur colloid? You end up with a gastric emptying study. For this study, remember that you are tagging the albumen on egg whites with Technetium 99M. You mix that with stuff like white bread, strawberry jam, some water. The patient eats it all. This meal has been standardized across patients, allowing us to know how fast the meal should move over approximately 4 hours through the GI system.

Now what if you drink it? Well, that can give you an esophageal motility study.

Another thing you can do at Technetium 99m sulfur colloid is imaging for splenosis. You can also use heat damaged red blood cells for splenosis imaging.

A final thing that I would keep in mind with Technetium 99m sulfur colloid is a bone marrow scan. That is useful in conjunction with a three-phase bone scan. The key is that the sulfur colloid shows you where the marrow is which, when combined with a bone scan, can be helpful. We will get into the nuances of this in later episodes. For now, just remember Technetium sulfur colloid does a lot of things, and one of these is a bone marrow scan.

Now, what about Technetium 99m MAA? This is something you should think of as a perfusion agent. Technetium 99m MAA is also very inert. This can do many things but remember first that this is a perfusion agent for a VQ scan.

Particle size can be tested here as well. For Technetium 99m MAA for perfusion imaging on a VQ scan remember the approximate range of 10 to 100 microns. I will give you a summary at the end of particle sizes that I would keep in mind for Technetium agents. For this perfusion agent, 10 to 100 microns range is important because that is the size that you need for these particles to get lodged in the smaller arterial branches in the pulmonary tree so that you can image those on the perfusion scan.
Another thing you could do with Technetium 99m MAA that is more historic is a brain death study where you are looking for perfusion to the brain. That is a less ideal imaging agent for brain death compared to Technetium 99m HMPAO or ECD.

Technetium 99m HMPAO or Technetium 99m ECD are similar exams in terms of testing for radiology board study. What they want you to know is that these are lipophilic substances that will cross the blood brain barrier. To confirm perfusion to the brain you are looking for uptake that is unequivocal within the brain. The hot nose sign on a brain death study is commonly tested. This sign is a manifestation that intracerebral blood flow has been blocked and causing shunting of blood into the external carotid artery circulation that manifests as a hot nose on imaging.

Technetium 99M DTPA can be used for the ventilation portion of a VQ scan. Other alternatives for ventilation imaging on a VQ scan exist. One is Technegas that is (currently) not FDA approved in the United States, but it is used in Europe and Australia and other places. However, the main alternative in the U.S. is Xenon. We'll get into details of VQ scans later, but for now remember Technetium 99m MAA

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is used for the perfusion part of a VQ scan and Technetium 99m DTPA is the Technetium agent most used for the ventilation aerosol portion of a VQ scan.
What about our Technetium renal agents?

There are really three renal agents that we should review here. The first is Technetium 99m DTPA. That should sound familiar. That is what I just mentioned for ventilation portion a VQ scan. If you inject this intravenously, it is filtered by the kidneys. We take advantage of that filtration to allow glomerular filtration rate calculations.

Technetium 99m DMSA is another renal imaging agent. I would keep in mind that it is a renal cortical imaging agent. Let me say that again as it is super important. DMSA is a renal cortical imaging. DTPA allows GFR calculation because it is filtered.

DMSA gets stuck in the renal cortex. Why is that useful? Well, especially in kids you can evaluate for pyelonephritis and renal scarring. From my experience this is not performed too commonly, but this is still tested. The most important thing for now is to know the difference between these three renal agents.

The third agent is Technetium 99m MAG3. MAG3 is really the workhorse of renal imaging that evaluates two principal things. First, MAG3 allows quantification of renal function, including blood flow, renal transit, and renal excretion. Second, MAG3 also evaluates for obstruction based on the halftime of clearance from the renal system. We will get into those details later. What I want you to know for now is that there are three agents for renal imaging with Technetium 99m. DTPA provides GFR calculation, DMSA allows renal cortical imaging, and MAG3 evaluates for renal function and obstruction.

Also remember that MAG3 is the best agent to use in renal failure because it has the highest extraction fraction.

Let us shift from the kidneys to the liver.

Technetium, 99m mebrofenin. What is that? Well, this is most used for HIDA scans. Other HIDA agents also exist, but the main one I would remember is mebrofenin. You need to know that mebrofenin is an analog of lidocaine with a similar chemical structure. It so happens that mebrofenin experiences hepatic biliary secretion, like bilirubin. We take advantage of that to show whether the hepatic biliary tree is patent and whether hepatobiliary circulation is functioning normally, as well as whether the cystic duct is patent for acute cholecystitis evaluation. We will get into these details later.

What about bone agents?

The main one is Technetium 99m MDP. Keep in mind this is a phosphate analogue. It readily incorporates into bone. We will spend some time on bone scans later.

There are two main varieties of bone scans. One is the full body bone scan commonly used for cancer valuation. The other is a three-phase bone scan more commonly used for things like fracture or osteomyelitis evaluation, or evaluation of a surgical prosthesis.

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Let us talk about Technetium 99m sestamibi and tetrofosmin. These are most used for cardiac perfusion imaging. There is some difference in uptake and GI and liver activity between these agents, but they both are used for myocardial perfusion imaging. They both bind to myocytes.
A key thing to remember with Technetium sestamibi is that this binds as a function of mitochondrial density and blood flow. Hence it is a great agent for the heart where mitochondria are abundant within the myocardium.

Sestamibi is also useful for parathyroid imaging. Sestamibi is also useful for tumor search, such as in molecular breast imaging, where you are looking for breast cancer. A common question on board exams is to show images from a myocardial perfusion scan, such as a SPECT image of the body that is rotating, and you are supposed to notice the presence of abnormal uptake in the breast that is breast cancer.

Technetium can also be tagged to red blood cells. This is important for our Interventional Radiologists because we can use Technetium RBC imaging to detect gastrointestinal bleeding with more sensitivity than they can using angiography. Technetium RBC imaging can help identify the source of a GI bleed in terms of vascular territory, or even just tell if there is an active GI bleed. The key for radiology board exams is to remember that tagged red blood cell imaging is sensitive for detection of GI bleeding to about .1 milliliter per minute of bleeding. On angiography, you need about one milliliter per minute to see the bleed. Again, that is .1 ml/min for tagged red blood cell scan 1 ml/min for an angiogram.
You can also use to heat damaged red blood cells tagged to Technetium 99m, as I said before, for evaluation of accessory splenic tissue/splenosis.

Another agent is the Technetium tagged white blood cell scan. The alternative to this is an Indium tagged white blood cell. We will get into some of these details later. The Technetium version of WBC imaging has a shorter half-life than Indium and that will typically be better for imaging children compared to an Indium WBC scan because you want to keep their radiation exposure lower. In this case, shorter half-life means shorter and less overall radiation exposure. Technetium WBC imaging also gives slightly better images because of the ideal 140 keV energy. However, there are some downsides with increased GI activity when using Technetium versus Indium, which is one reason why you would consider imaging if you are evaluating a GI process.

Let us go through some high yield, commonly tested questions/scenarios for radiology board exams:
With Technetium RBC imaging, if you get a poor tag (meaning the Technetium and RBCs do not bind well) you are going to end up with free Technetium. What is one key for identification of free Technetium that I told you? Gastric uptake. So, if you see a lot of gastric uptake on a red blood cell scan wherein GI bleeding is suspected, how do you know if it is a gastric bleed or only free Technetium?
The answer is to scan the head and neck. Remember that free Technetium also has a lot of salivary gland uptake. If you see a hot stomach when you are evaluating for a GI bleed, the next step is to image the head and neck. If you see uptake in the salivary glands, it is likely not a bleed, it is consistent with free Technetium. If you see no salary uptake, you have a gastric bleed.

Let us talk about a few key points for Technetium 99M MDP bone scans.

If you see multiple areas of uptake in the lung, you should think of calcified or ossified bone metastases to the lung which are classically associated with mucinous adenocarcinomas or osteosarcoma metastases.

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You should know that a single hot lesion on a bone scan has about an 80% chance of being benign. This is commonly tested. if they ask you what cancer is more likely to show as a single hot lesion in the sternum, your answer is breast cancer.

What if you see the bones super well on a bone scan but you are missing activity in the soft tissues and there is no kidney uptake? This describes a super scan. You will likely see questions on this. A super scan indicates that there is diffuse osseous metastatic disease, so much so that the bones are taking up all the tracer. Little to no tracer is left for the soft tissues or renal clearance.

What if you see super-hot kidneys on the bone scan?

Think of two main things. One is hemochromatosis. The other is very recent chemotherapy.

What if on a perfusion scan for a VQ study you see a lot of brain uptake?

You should be thinking about a right to left shunt. These stunts may be caused by things like congenital cardiac anomalies and arteriovenous malformations.

In terms of particle sizes:

I would know the particle sizes for MAA, DTPA, and sulfur colloid. All of these are in micrometer scale. For MAA, you are looking at 10 to 100 micrometers. For DTPA, which is the inhaled agent in a ventilation scan, you are looking at about 0.1 micrometers. For sulfur colloid you need to remember 2 sizes. For unfiltered sulfur colloid, 1 micrometer and for ultra-filtered sulfur colloid 0.1 micrometer.
Now there is a range of particle sizes with all of these, but if you remember one central number, such as above, that should help on multiple choice questions.

Earlier in this episode, I did say that ultra-filtered sulfur colloid has a particle size of under 200 nanometers. Now this is real life. On board exams you do not know with certainty whether they will ask you a question in nanometers, or micrometers. A micrometer is the same as a micron.

My recommendation is to remember 1 number and know how to convert between units. For example, earlier for ultra-filtered sulfur colloid I mentioned a particle size of 200 nanometers. More recently, I said 0.1 micrometers. Technically 200 nanometers is 0.2 micrometers. Do not despair. That is close enough to 0.1 micrometers and remembering either of these should lead you in the right direction for multiple choice exams.