Advances in Thoracic Imaging for Lung Cancer (Video Transcript)

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So I'm just going to try and give an overview of some of the newer techniques that we have available in chest imaging today. And due to the time limitation, I'll just mainly focus on some of the ones that we're using here at the University of Chicago. And many of these are not universally available.

Specifically, just to introduce the concept of digital chest x-rays, which we use now, what we call dual energy imaging, which we also use routinely now at the University, and a little bit about computer aided diagnosis.

Chest x-rays don't get a lot of attention these days in the press, because CT obviously is advancing very rapidly, but it's interesting to reflect that the large majority of lung cancers are still detected on chest x-rays. Just because Dr. Hogarth said, we often pick up things we're not expecting and many, many people have chest x-rays compared to the number of CT scans.

So we do find most of the lung cancers initially on chest x-rays. So we believe it's important to extract all of the possible information from a chest x-ray with these various technologies.

I'm going to say something about CT which we call multidetector CT now. Some of the new display options and some of the new kinds of software that we can use to improve the diagnostic yield.

So the situation is that we're now doing digital radiography routinely, and only a few years ago, we were using film, x-ray film which is a bit like photographic film, and that could be very good, but once we have the images, we couldn't do anything with it. And it was--just one copy. So digital radiography comes in two forms; what we call CR, computed radiography, and DR for direct digital. It doesn't really matter and you don't have to understand how the chest x-rays are made. But you should know now that most hospitals are using this kind of digital image capture. Some of the advantages that this gives us are in image quality. We can see things we weren't able to see on those older film images. We've more dynamic range. We can do image processing and we have additional advantages too. Such as the ability to interact with the image, and of course, to access the image from throughout the hospital or indeed, from other places throughout the city or throughout the country. So when I'm at home, if I get a call, I can look at a chest x-ray or CT scan. So these are the advantages of digital imaging.

And of course, now we work at work stations, not at light boxes. And this is the advantage that we can apply these sophisticated kinds of software that we didn't have available in the past.

So what can we do with this digital chest x-ray that's so important for lung cancer? Well, the problem with chest x-rays is, they have a lot of information, but it's very hard to pick up all of the details in the chest x-ray, even with experience. It's very easy to miss a small lung cancer, such as in this chest x-ray here. And I'm sure you know the chest x-ray shows the heart, and the lungs which are the darker bits, are relatively transparent. But these lines here are the ribs, and the ribs block part of the lungs and that's part of the reason that we can actually miss seeing things in chest x-rays. This would be the anatomical corresponding section to that chest x-ray.

So if we come back to this lung cancer, and perhaps you've noticed it at this stage, there's something there in the middle of that right lung. And it's very faint, it's hard to say what it is. It could be a pneumonia. It could be a lung cancer. Part of the problem is it's been blocked by the rib. How do we see it better?

Well one thing we can do is a CT scan. And here is a CT scan and it clearly shows what is actually a small lung cancer, which was hiding behind the rib in the chest x-ray.

And we know that this happens a lot of the time. In fact, if you go back, if you've had a previous chest x-ray and you have a lung cancer detected, it's very frequent that there will be a lung cancer very small one, perhaps, visible in retrospect on the earlier exam. This happens all the time. It doesn't mean that there was a serious error. It just means that it was very hard to see. Here's another cancer that was hiding behind the bone.

One of the things we've found about these missed cancers is that over 80%, they are hiding behind ribs. And on the right hand side, you see the location of the series of missed lung cancers that was found in retrospect. Most of them are hiding behind the ribs. How can we deal with this?

Well fortunately, we have a technique now, we call dual energy or energy subtraction imaging and we use this routinely now at the University, both on inpatient and outpatient side. And this works like this. We take a regular x-ray exposure, and the x-rays go through the patient as they normally would, they hit plate. Now in traditional x-ray, even digital x-ray, a lot of those radiation photons, go straight through the back of the plate and just get wasted. They don't get recorded. So there's a system and it's commercially available now, where there are two plates. The second plate, which you see behind the first, actually catches those higher energy photons. And we record both the low energy and the high energy photons. This is done automatically. A computer analyzes the difference between them and the bottom line is that we get three chest x-rays instead of one, for that single shot. So here's the standard x-ray. Here's what we call the soft tissue image. Notice that there are no bones showing in this. The bones are being subtracted by the computer. And the bone image, which we show the bones as black, just for convenience, and it only shows the bone. It doesn't show the lungs. And there's actually little black spots down behind – beside the heart order here, which is a little calcified, healed granuloma, which shows that it is benign. So there's important information on that.

But you can appreciate that it's easier to find cancers in an x-ray image like this, than in one like a traditional one on the left that has all the bones in it.

And as we look at these on the workstation, of course, we look at them in sequence, like this. So we just scroll through them, quite quickly and we can see if there's anything hiding there.

So that's one of the kinds of new technologies that we use. Here's an example of where it could be useful. Here's another patient with lung cancer. You may not notice it, right away, it's sitting out there in the middle of the left lungs. But again, it's hiding behind the bones. We look at the dual energy image; it's much easier to see. Again, this is another example of why we use dual energy routinely, because we don't always expect to find lung cancer. Most people have a chest x-ray do not have it. They're going to have other problems. But in the cases that do, this gives us a big advantage. Again, the standard image on the left, dual energy on the right, and here's the CT scan. On the CT you clearly see this lobulated cancer, very typical of a primary lung cancer, hopefully, still curable at this stage.

What else is this good for? Well, as I've shown you, it can show calcium which tends to accumulate in old, healed infectious lesions, due to a fungi like histoplasmosis, which are common in the midwest or perhaps due to TB. So here's a little spot in the lung. But it's down there. And if we look at the bone image, it shows clearly that it's black. Which means it's not a cancer. It's benign. We don't need to do a CT scan. On the other hand, if we look at the soft tissue image up here, and we take out that catheter, you notice that there's a cancer that was hiding behind it up here. And it was hiding behind both the catheter and the rib. So again, an example of a cancer that was hidden by the bones and by overlying structures, that we can show with dual energy imaging.

So again, an advantage for lung nodules due to cancer, also an advantage for nodules that may be questionably calcified. Here's a nodule could be a cancer. Normally, we'd have to do a CT scan to find out if it is lung, but fortunately this was done with our dual energy system, and we have a bone image and the bone image shows a little calcification there. It shows some dark spot within that nodule, which means that it's not a cancer. So we don't need to do a CT scan. So this actually saves a lot of trouble and a lot of worry and in many cases, we can send the patient home without further investigation.

The other thing you should know is that it doesn't use any extra radiation. It doesn't cost any more. Most of the time you wouldn't even know that you're having this kind of exam and for the radiologist, it's a matter of just a few other seconds to look at these extra images. So, it's certainly valuable and we feel that it's worth using it in every single case. It has other advantages, I won't take the time to show you, since we want to move on.

I'll show you an example of something else that we've worked on here at the University. We actually developed this system here and this is one where we can do an electronic comparison of a new and an old chest x-ray. Here's a chest x-ray that shows something that we were concerned about, up in the apex of the lung. It could be a scar, perhaps it could be a cancer.

Here's the dual energy version; it helps. But it doesn't really tell us exactly what it is, or it has changed. On the other hand, we had an old chest x-ray here from the year 2000 to compare it with the new one from 2003. There does seem to be a change. The position might be a little bit different. So we want to be sure. So we decided what will be very useful if we could just take the old chest x-ray and make it fit right on top of the new one, and somehow subtract it, so that we would see the difference. That's what we're trying to do with our eyes, but it's very hard to do.

And we developed actually a system here that will actually warp the old chest x-ray to compensate for those differences in position, so that it'll fit exactly. Then we can subtract it and if there's no difference, it's going to look completely gray. Like the image at the bottom.

On the other hand, in this case, it turns out that there were two lung cancers, one at each apex, and since they've changed, they appear black. So they appear very obvious on what we call the temporal subtraction image. And here's the CT scan that confirms those two cancers. So this is another example of the kind of image processing or image analysis, computer aided diagnosis that we can do now, which wasn't available when we were using film.

And this is actually something that's commercially available in Japan. It's not yet available in the United States, but it is under investigation and hopefully, it will be a product in the future.

Let me say a few words also about the diagnosis of nodules by computer aided diagnosis. And there are several computer aided diagnosis systems being developed and not just for lung cancer. But lung cancer is what we're talking about so let's focus on that.

And the idea of these systems is that the computer will actually analyze the chest x-ray, and it will compare with examples that the computer has learned to recognize of cancers in other kinds of chest x-rays. And it will put a circle around anything that the computer regards as suspicious. The computer will not read your chest x-ray yet by itself. It will just point out an area that's suspicious. So here's an example. We have a chest x-ray with a very faint nodule in the upper lobe, again, hiding behind a rib as they often do.

Now the computer has correctly put a circle around this nodule, so it's telling the radiologist, you better look here very carefully because there's something suspicious.

If it worked like this all the time, everyone would be using it because it would be obviously a very bad idea not to, but what happens in practice with these systems still is that as well as this nodule, it marked another area here which is not a nodule, another area here which is just a rib crossing and another area here which is a vessel on a rib. And these are what we call false-positive protections. In other words, computer is worried that they may be cancers, but we can recognize they're just normal anatomy.

So the way that these work is they put several marks out there, usually and we have to decide whether it's really a cancer there or not. On the other hand, they get better all the time. Every year there's a new version just like with your computer, whether it's for photography or for word processing, there's a new version of the software released regularly, and each one is better than the last. So eventually, the accuracy will get to the point I'm sure where we will have very few false-positives in these systems. And we work currently with manufacturers to try and develop these and try to improve them. When we do tests, which we call observer tests, where we show a radiologist or a group of radiologists a chest x-ray without computer aided diagnosis, then with computer aided diagnosis, we find that they score much better for detecting lung cancers when they do use computer aided diagnosis.

So that's one of the areas we're particularly interested in here at the University, although we don't use it routinely yet, we do a lot of research in this area. And we expect we are going to start using it pretty soon.

So let me move on to CT, which is a lot more used than in chest x-ray and let's look at how CT has changed over the years. Until the early 1990s, when you had a CT scan, you would lie on a table and the table would move an inch or so at a time, and the gantry would rotate around you, and obtain an image. And then the table would move again, and the gantry would rotate again. Then we went to what's called spiral CT whereby the table moved continuously, as it does now, and the gantry continues to spin around you, and it generates a continuous series of images. And that was a big advance.

Then, about 1994-95, we got to the point of multidetector technology and at that point, devices were invented where we could collect four slices at one time. That was very exciting, because that meant we could scan much faster. Within a single breath hold we could get through the entire chest, even on someone who is short of breath, and we could scan with thinner, finer sections.

Now we've moved beyond that, and our most basic scanner here now is a 16 slice, which is quite advanced. We also have a 40 and a 64 slice scanner, and almost every year now, the technology advances. And there has been a 256 slice scanner invented. What does this mean practically, more and more slices? Well, what it really means is that we can scan much, much faster. Why is that important? It's important because if you're sick, you can't hold your breath very well. Secondly, you can't stop your heart from beating, even if you're well. And if we want to obtain images of the moving lungs and the heart, we need a very fast scanner and we need to obtain very, very thin slices very quickly.

So let me just show you an example of how this would work. In the old days and we joke the old days were like five years ago, when we had the older scanners, we would look at the scans in this way. We would look at cross sections, what we called axial sections like slices through the chest. This is upper, this is middle and this is the lower chest, and we'd also look at versions of the same slices at a different window level, so that it's set more to show the soft tissues of the mediastinum as we call it, and that the other areas of the breast and the abdomen and so on.

What we have now is the option of doing much thinner sections and in viewing the chest in a lot of different ways on a CT scanner. So routinely now, at the University, we require slices that are 3mm thick and 1mm thick on every patient, not just patients with a special problem. And again, this is our policy that we never know when the information is going to be useful. It is a lot more information to store. It's more work in some ways to look at it, but we find that it's worth doing. So here's a 3mm slice on the upper left, a 1mm slice down here and you can see the finer detail in the 1mm slice. We go through the chest at 1mm, that's about 350 slices. It's a lot of pictures to look at. So we need different ways to look at it.

This is particularly useful if we're comparing say a small lung cancer. This is a close up view of a lung cancer, here it is, when it looked like it might be just a small scar in 2001. The patient came back in 2002, 2003 and 2004 and eventually it has grown into a small lung cancer. And this patient, for various reasons, was not a candidate for surgery or it would have been removed sooner. But you can imagine if we're trying to see the detail of very small lesions like this, it's important to have thin sections so we can compare exactly the same part of the same nodule each time and be really sure whether it's changing or not. Cause if it's growing, generally we want to do something about it. If it's not growing, we may want to leave it alone.

The advantages of these fast scanners is that we have, as I say, very thin slices and this results in what's called isotropic vox cells, which means we can slice the chest now, not just crosswise, but coronally, and sagittally, in other words, front-wise and sideways. We can look at it in a lot of different ways and that's an advantage for recognizing abnormalities.

Here's an example. You can recognize the front of the chest, as you might see it on a chest x-ray, except this is a slice and this is recreated from a scan. Shows a large cancer bulging into the airway here. And on the lateral view, we can show the shape of that cancer as it's bulging in. And in fact, as Dr. Hogarth showed you a bronchoscopy. Showed you a movie as he puts the scope down into the airway, we can do what we call a virtual bronchoscopy. Just recreating from these pictures, the inside of the airway. So we can show the physician what it will look like when he puts the scope down there. And at the bottom you see these gray images represent the appearance as we look down through our virtual bronchoscope, and see this cancer that's in the airway.

In fact, I can show you a movie, hopefully, that will show how this would look on our screen. It's a reasonable simulation of what real bronchoscopy looks like and this is airways of a real patient, acquired from a fast CT scan with a 64 slice scanner. Now we can do this on any patient now that has a chest CT scan. We don't need to do the scan in a different way. It's information is available and we can do this when we need to do it. So we can analyze the inside of the airways in a way that wasn't possible in the past.

We can also reconstruct the airways. In this patient, there's a narrowing in their trachea and we can show it from the outside and we can rotate this in three dimensions, which is helpful to the surgeon and again on the right side, you see the virtual bronchoscopy.

Another example of a way that we can slice the chest to show the airways and the blood vessels, and the bones in a coronal section. Sometimes it's an advantage to make thicker sections like these, which are called maximum intensity, where we can show branching vessels and we can more easily distinguish branching vessels from nodules. And we can indeed use color and we can use various kinds of renditions in various special applications, all using the same standard data set. So the point being, every time you have a scan now, we acquire so much information that we can reproduce it and we can use it in different ways and we can process the information depending on what question is asked.

We don't necessarily look at all of these images in every case, but we can if we need to. We have that option. And we can move through the abdomen and the chest, in a way that was not possible in the past from front to back like this, which is much easier. Let me just show you a practical example where this maximum intensity would be helpful.

Here we have a little nodule in the periphery of the lung. Here you see the blood vessels. You notice how three-dimensional the vessels look in this kind of a view. Here on the other hand, is a standard slice. We do see the nodule, but it doesn't look that different from these little blood vessels that we're slicing through. Here's a 1mm section. Again we can see the nodule, but it's very easy to overlook. On the other hand, on the maximum intensity projection, we can more easily distinguish the vessels from the nodule, because we showed the length of the vessels and we showed some three dimensionality. So this is something that again, we do in every single case and we find it very helpful to detect small nodules.

How would this work in a clinical case? We start with a chest x-ray. A little nodule in the lung. Could be a lung cancer. We need to do more. It is a dual energy chest x-ray, so we take out the bones. We confirm there is definitely something there. We do a CT scan. We look at it in a coronal dimension, like we're looking at it front ways on. We can see it isn't actually very round, like most cancers. It has a very straight order. That makes us wonder if it might be something due to for instance, infection. We look at the standard slice. It does look rather spiky like lung cancers do, which we call spiculation. But also a few nodules around here. Some of these are vessels, some are nodules. Hard to tell. So we look at our maximum intensity view, now it's very obvious that we got a cluster of little nodules all around this. This is actually an infectious lesion, which eventually went away. And it was not a lung cancer, but by virtue of this kind of analysis, we were able to suggest that this was probably not cancer. We were able to save the patient having surgery or a biopsy. And granted, Dr. Hogarth, could have applied his super dimensional bronchoscopy to this lesion if necessary, and got a diagnosis without too much danger that way.

Other kinds of views we call minimum intensity projection, which show the airways very nicely, show how the airway branches into that lesion. A patient with severe emphysema, which you know results from smoking, often associated with lung cancer, produces these black areas in the lung. Sometimes we like to know not just is it there or is it severe, but how severe is it? How can we measure this kind of disease and now with this kind of automated analysis, we can actually provide numbers. We can not only provide a color map, all of the red areas here are areas of emphysema, resulting from smoking. Usually most severe in the upper lobes. But we can actually provide numbers and we can say how much of a lung is affected. What's the total percentage? And this has got implications, of course, for lung surgery. Whether the patient has cancer or some other kind of disease. This is just one more tool that's available.

Cardiovascular imaging and computer-aided diagnosis are two other areas. I'll start first with briefly, with computer-aided diagnosis. Now I talked about how computers can detect nodules on chest x-rays, they can also do it on CT scans. Here is an example of a nodule. This was a metastasized cancer. This is a cross section of a CT. This is part of the heart. This is part of the airways. We're looking at a thin slice. Computer-aided here has actually detected this nodule, and has automatically outlined it. On these other views, it shows the same nodule in different kinds of perspectives, and it also shows a 3-dimensional rendition of the nodule.

And I can show you a brief movie here, that shows how the computer can actually rotate this nodule in space to show us how it is related to the blood vessels, if we have a question whether it is a real nodule or not. And also, how it can actually automatically outline the borders of that nodule and it can, in fact, compare it to the previous scan to tell if it's grown.

So a lot of this is becoming more sophisticated and more automated, and this illustration is from a firm that we're starting to work with, that produces this kind of very advanced software.

So let me move on from there. Another thing we can do with computers, again, it's just starting now. It's not a product that we can use every day, but we're starting to look at how we can tell very small benign nodules, due to say infection from ones that are malignant due to cancer. The two on the right here are due to cancer, the two on the left are due to infection.

They look very, very similar. But with the kind of detail that we have available now, we've got tools that we can use to help us guess which is this going to turn out to be? In many cases, we're still going to have to follow up. We're still going to have to see if it grows. But this gives us a better chance of detecting early on what it's going to be.

And let me just mention PET scans. I'm sure many of you who are aware of cancer know about PET scans. There's a very exciting new technology that allows us to look at the metabolism of the tissue. Here's a CT scan showing us a suspicious nodule and again, it could be a cancer but we can't be certain from this picture. On the other hand, with a PET scan shown here, this is a cross section and this is a coronal view, shows that the nodule lights up and the lymph nodes in the mediastinum also light up, indicating that this is an active lesion due to cancer. And again, here are lymph nodes lighting up superimposed on the actual CT scan showing that the lesion has spread to the mediastinum.

And this is extremely valuable particularly when we're staging cancer, because we found that this is much more sensitive than the CT scan. Sometimes lymph nodes are not enlarged and they light up very dramatically on a PET scan. So we're using this very frequently now in combination with CT.

Let me just say a word about lung cancer screening, because it's very much in the news and I'm not going to say a lot about it, but I think it's confusing for the general public now, because you hear that there are good results from cancer screening, and yet you hear cancer screening isn't recommended for lung cancer. And it is a confusing subject, but basically, the problem has been so far that when we do CT scans, on the patients who are at risk for lung cancer, we find a lot of nodules. Most of which are not cancers. So in the so-called LCAP trial, 23% of the patients were found to have nodules. In the Mayo Clinic trial, over half of all the patients were found to have nodules. So you should be aware that if you do have a screening scan for whatever reason or someone you know has one, they should be prepared for having a result that shows a nodule. It doesn't mean that they have cancer, but it means there's something there that has to be watched. And in many cases, or in most cases, these patients will have to have another scan in six months time or a year's time to see if that nodule changes and grows before we know the answer.

So there is a certain commitment in going into lung cancer screening. At the same time, we're very optimistic that we're going to find many of the small lung cancers before they have spread.

The other interesting piece of information to come out of this is that there is a relationship between the size of the nodule and the likelihood that it's going to be malignant. So as the scanners get better and better, we see finer and finer detail. We see tiny nodules now, 1 or 2mm that we could never have seen years ago. And the large majority of those are just old infections. They're not cancers. And the good news is, that if you have a nodule that's less than say 5mm in your lung, and even if you're a smoker, all other things being equal, the chance of that being a cancer is about 1:100. It's very, very low.

On the other hand, if there's a larger nodule discovered, the chance of that being cancer is a good deal higher. And so on. But we do pay attention to the small nodules because we want to catch these cancers before they're too large. But we don't worry too much about very very small nodules that are picked up, especially in young people or especially in people who are not smokers. And in some cases, now, we recommend that the patient just not worry about them and not follow them.

On the other hand in a smoker, in a patient who is at risk for lung cancer, Dr. Hogarth described, we certainly want to follow these little nodules. We want to find out if they grow. If they grow, we want to consider doing something to catch them.

I'll just mention imaging the heart. And try the XCT, because that's in the news too, and that's something that we can really do very well with the new 64 slice scanners and beyond. And that's actually where the new scanners have the biggest impact, because the heart of course, keeps moving. And it keeps moving pretty quickly, even if we use drugs to slow it down. But these newer scanners are fast enough that they have allowed us to actually show the coronary arteries, and this is very exciting because in the past, you needed a catheter to put into the heart, to squirt dye into those arteries to show them. Now we can just inject x-ray dye into an arm as you lie on the CT scanner. We can acquire a picture of the heart and we can get a pretty good idea of whether your coronary arteries are normal or if you have disease.

So this is now become quite a common examination, and it's going to become more so in the future.

Here's an example of the kind of detail that we can show in coronary arteries with one of these 64 slice scanners and a so-called gated scan. I should say parenthetically, a routine scan however, will not give you this information. It must be gated with cardiac cycle, meaning that we just image during certain phases of the cycle. The downside is that it takes a lot more radiation, takes a lot more time, as far as hooking up ECG leads. So this isn't some information that you'll have from your routine CT. If we decide to do a cardiac CT, we can get these kinds of images and this kind of information, showing the coronary arteries coming off the face of the aorta or the pulmonary veins as is the case here. Very easily done with currently available software.

So basically that's what I wanted to talk about and what I'd leave you with is that although chest x-rays have been around for a long time, there's actually a lot that we can do with them, and a lot that we are doing with them with the new technology to make easier to pick up small lung cancers. In the case of CT scanning, the technology is evolving very fast, and it's likely we're going to get even better results from compute-aided diagnosis in the future. Thank you.

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