Course on Introduction to Medical Imaging and Analysis Softwares
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Module 01
Lecture 04: Ultra Sound Imaging

Welcome today we are going to learn about an interesting imaging modality and that is called as ultra sound imaging. Now you might be quite aware like some of you might be aware of it and might have heard about this particular name called as ultrasound and obviously it creates quite a buzz in everybody's mind as to what is this small prefix of ultra doing along with sound over there.

Now to give you a very simple hint over here it is something to do with the frequency in which we are going to work out over here and all comes down from the point that these frequencies are above our standard audible limit so human ears can hear upto 20,000 hertz or 20 kilo hertz basically. So if you are above that particular frequency then you are in something called as an ultrasound limit as per our standard parlance.

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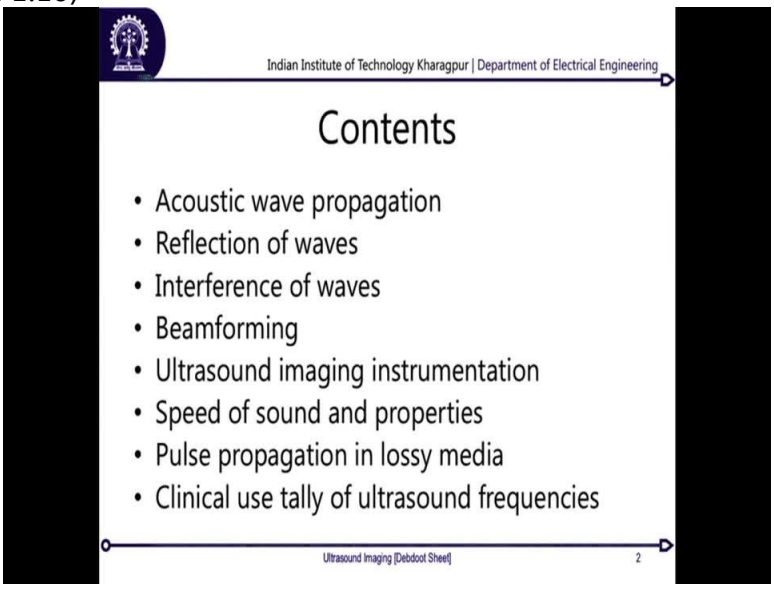

Now, how we are going to cover down is something on this sort that initially I would be speaking about acoustic wave propagation in media and from there I would be moving on to how waves are reflected. And so this part is just a very basic refresher of some of the concepts you had done

in your high school level physics as well. But again coming down from the perspective of how we are going to use all of these wave propagation and everything in order to create an image of our own internal body what is called as soft tissue and soft tissue made up organs.

So after reflection of waves I would be speaking about the interference principle between waves and which actually helps us in creating a very practical application which is called as beam forming in ultrasound. Now, often if you go through later ages you would be coming down through these terms which called as ultrasound beam. Now in general when we will be going through these physics part of it you would see that this is since this is some sort of a mechanical wave, so they always emit in terms of wave forms.

And these these wave fronts are always spherical in nature, so they are not necessarily something which will follow one single packet as in for laser lights where you can always have a beam. So but there is a analogy which we draw over there and use some very tricky physics and instrumentation combination together in order to get ourselves something which we call as a beam.

So from there after we understand the basics of this instrumentation I would be coming down into what an ultrasound imaging instrumentation is and what are the different blocks which make up a very standard ultrasound system which is used. so this standard ultrasound system design which we are going to read over here is not limited to only medical applications, so they can have meteorological applications as well they can have ground penetrating, surveillance applications, they can have applications in mines and multiple innumerous ways in which ultrasound imaging is used other than medical as well.

Now from there I would enter into some specific properties of sound waves and speed of sound in different common materials and media. And from there we will be coming into something called as pulse propagation losses in inside a media or what is called as a lossy media and what happens to the pulse and the total energy which an ultrasound wave carries. And from there I would enter into some clinically used frequencies and what are the ways in which clinically uses of ultrasound and some photographs and some basic refresher on what an ultrasound machine looks like.

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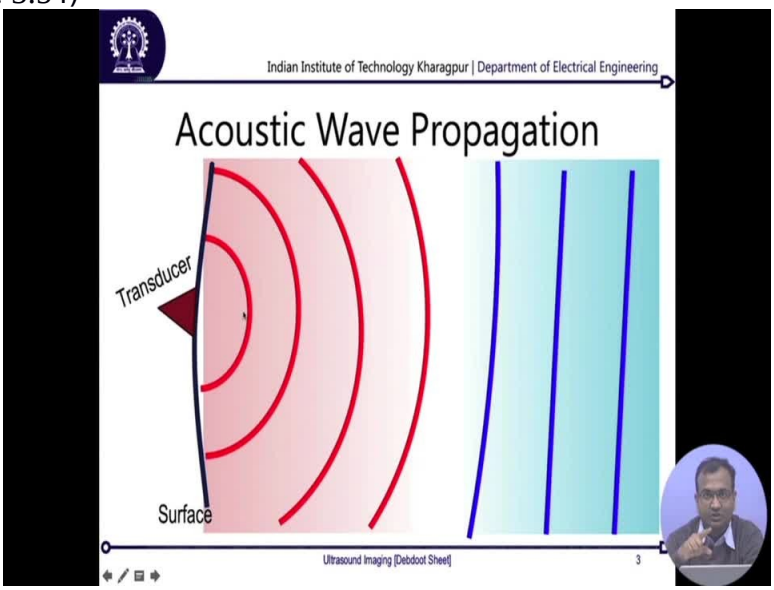

So with that let us start with it now initially say you have this sort of a problem so let us consider a surface and this can be a natural surface so you do not need to have a very flat planar surface in any way, you can have some sort of a curved surface over there. Now for ultrasound you will have a transducer which will be placed on the surface and for all practical purposes this transducer has to placed in exact contact with the surface, you cannot have an air gap or anything.

So you have to place the transducer actually on the surface itself that is why if you are going down for an ultrasound imaging of some sort to a diagnostic center you would see that they would take the probe apply some jelly and then place it directly on contact of your surface. So that is the way how the whole imaging has to work and we will come down to eventually down the slides we will come down to the rational as to why you need to put it close to the surface and if you are not putting it exactly on the surface then what is the disadvantage for this kind of an imaging.

Now say this is this transducer is placed over there and now it emits a small vibration a small bit pulse say there is one acoustic pulse which is emitted from there. Now what it is going to do is going to be something like this. So if you look at the principle wave front over there so after a particular gap of time which you would see this is where the principle wave front is located, now that is going to propagate down the line over here. Now you would see that there is a change in

color which we have on the wave fronts over there and these wave fronts are basically all the locations which are in the same phase at a particular given point of time, okay.

So we are basically probing after a fix period of interval over there and just drawing down the contour of all the points on that wave which are in the same phase over there, okay. So now for all practical purposes we will assume that this is the point where the amplitude of the wave is maximum after a given time interval over there and that is how it is growing. So imagine you throwing a stone in a pond of water or in a small bucket of water and then you would see circular wave front which is just propagating along over there.

So imagine a similar kind of thing happening and that is what happens with an ultrasound within your body as well, okay. Now from there you would see that initially there would be spherical and now as the radius of this sphere keeps on increasing, so your spherical surface now starts becoming a planer surface given a small interval you are looking at it. That is why say our earth is something like a sphere which is an oblates spheroid as such.

Now, on this if you are looking at a small portion of land, then it would always appear as flat. We are not able to see the curvature of the earth in anyway. So over here also it is the same thing. As the wave front keeps on going bigger and bigger and you would see that eventually with increase in radius your wave front appears as if planar. Now, this is a beauty which ultrasound provides and is actually necessary for the kind of imaging which we are going to do over here.

So what we call this initial part near the transducer is called as the Fresnel zone or the near zone and this is where you have the spherical wave front still present over there and this is not something a zone which is good for imaging. So we never do an imaging classically in the Fresnel zone. Now the other zone where you have all of these flattened out wave fronts is called as the Fraunhoffer zone or the far field and typically this is the zone which is very much preferred in order to do an imaging.

And we will come down eventually as to why it is but just make this concepts clear the near zone is called as the Fresnel zone and the far zone is called as the Fraunhoffer zone over there. And the far zone you will always have a planar wave front.

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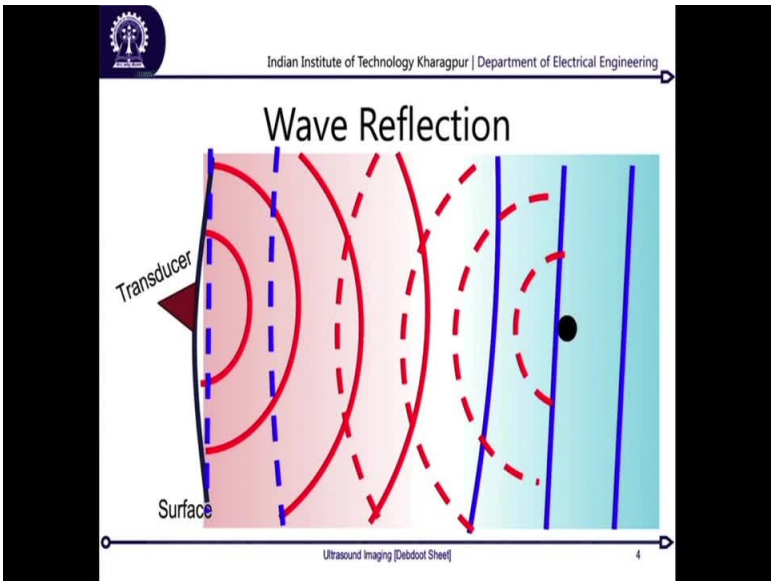

Now, since in ultrasound the idea is that you have a pulse which is propagating through media, its strikes a particular body and comes back, okay. So when it comes you can gauge basically if you know the sound the speed of sound in that particular media, so you just need to look into the time it has taken to come back and from that you can estimate at what distance was that particular object which it was striking and which was echoing back over here.

So that is how we use this whole concept for imaging. So over here, imagine that there is a point in media this point which is supposed to be the first obstruction from where the wave will get reflected, okay. So in that case, what happens is that the forward wave would be traveling and eventually it will strike that particular media and from there you will have a reverse travelling wave, okay. And if you have more thanpoint say there is another reflector over here, there is another one over here you would see multiple of those reflections coming back, but they will come down after a different period of time, right?

So this is one concept which will happen over here which is the main way of how you are going to do this whole of imaging, okay.

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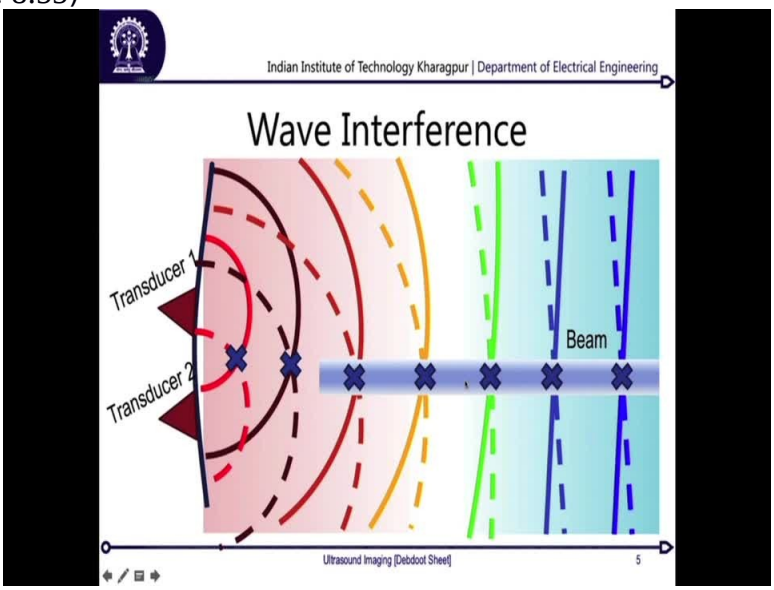

Now, from there let us look into another interesting phenomenon which is called as interference between waves and this is where we are going to enter into what an imaging with ultrasound waves because till now if you had scene you had one transducer and it was sending out waves it was striking somewhere and coming back, okay. So you basically had no control over where that point was located, except for the depth from the transducer you did not have control over where in like orthogonal to that particular line is the point located.

So on the 2d space you can never figure out, you just have a 1d way of figuring out where that obstruction is located, okay. So this wave interference is something which helps us in solving that problem as well. So what happens over here is we do not have one transducer any more so now it is say multiple number of transducers. So let us start with just two transducers and see how these interference happens and eventually we will extrapolate this whole methodology to multiple number of transducers over there.

Now say if there are two transducers and both of them are fired at the same time, so basically the same wave pulse would be emitting together from both of them and they could be travelling down the line, okay. So if both of them are fired together you would see that this is the solid one is the wave front for the transducer 1, the dotted line is the wave front for transducer 2 and somewhere over here there would be intersecting each other as well and that is the point where

they will there would be heavy amount of constructive interference between these two wave fronts because both the wave fronts are in the same phase, okay.

Although they coming from two different sources but since they are on the same phase so there will be constructive interference between these two wave fronts. Now when there is constructive interference you have a summation of amplitude. So the power of the signal which is square of the amplitude is obviously much higher than anywhere else over there. So all of these regions will have a much lower power of this acoustic pressure wave than the point where which is marked by cross over here, okay.

Now as these propagates and in the second wave front so once this completes one time cycle and goes to the next time cycle over there also again it will be interfering with each other, okay. So you will have this point which has the highest magnitude. Now over time it will keep on interfering with each other and this is how these interference points will be defined.

Now if you look clearly and the total acoustic pressure which is present across over here or the total acoustic power which is present in this media is maximally concentrated along these points which are marked by a cross, right, that is already established to us in a good way. Now the point is if this is as such going to be the maximally so a point where you have maximum energy concentration, so this packs the whole thing into some sort of a beam whereas a beam is basically defined by where your maximum energy concentration of whatever energy you are going to carry on over there.

So that defines this whole thing as a beam of acoustic pulse, okay. Now look into one thing, as we were entering into the Fraunhoffer zone which is my far field, my points were aligned along a straight line on the beam. Whereas, when I was in the Fresnel zone they keep on changing their location. So this is sort of not in a long range correlation. Over here hence forth if I go these beam will keep on being a straight line, whereas over here they have different points where they are going to interfere with each other, okay.

And that is the reason why in near field we do not do an imaging because you do not have a very concentrated beam formation happening in the near filed, although amplitude of the energy signal is much higher over there. So why that is higher eventually come down in material

properties and we will discuss that. As the wave keeps on propagating with media there is some sort of a loss in its energy as well. So that we have ways of compensating for that as well.

But for the time being remember that we do the imaging in the Fraunhoffer zone or the far field only for the reason that you have a very distinct beam formation happening over there, okay. Now from here that we know that beam forming happens only due to interference we are going to enter into this whole concept of beam forming or what do you do on the instrumentation sides so that you can actually form a perfect beam over there.

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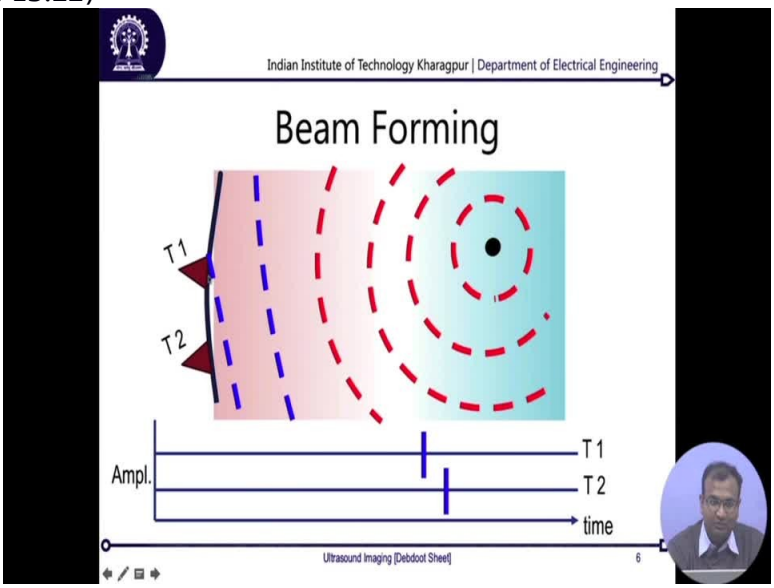

Now for that, what we do is something of this sort. So say you have the surface and 2 transducers present over there, right and you have your reflector over here. Now say that you (thi) this you had already formed the beam during forward transmission which is your acoustic beam was already sent, okay. And now this point was located on your acoustic beam and this starts sending out.

So now your transducers are behaving in a receiver mode no more in a transmitter mode over there, okay but when it is behaving as a receiver mode it is still will have a way that the same beam will reach one of like both the transducers but with some sort of a delay and look over here, so if we look into time versus amplitude plot of the signal received by both the transducers now T1 and T2 and try to plot it down.

So this is how the wave front is going to propagate and now if you see that the wave front first hits T1 and that is why you get 1 pulse over here at T1 and after sometime after a time delay it hits this second transducer which is T2, so you have this delay over there. Now, somehow we need to keep in mind that by looking at these time delays of subsequent ones coming down at say if there is T3, T4 eventually. So there would be subsequent delays over there, whereas if there is another transducer over here which is called as T0, then that would be preceding T1 as well in the pulse arrival over there.

So looking at all of them together there should be a way in which we can estimate in the 2d space where this particular point is located, so our earlier problem which we had solved is what is the distance from the transducer along the line which is orthogonal to the transducers plane, okay. Now the point is if you want to look into this particular direction, then we can use this information about how much delayed it is between arriving and different transducers in order to find out where it is located in space. Now if say this point this particular reflector is located exactly between these 2 transducers then both the waves will strike both the transducers at the same point of time, this is what (())(15:37).

Now let us derive a mathematical model because this is guided down by a pure geometric model which is a very straight forward way of finding out and that is why the instrumentation is not so complicated in any way.

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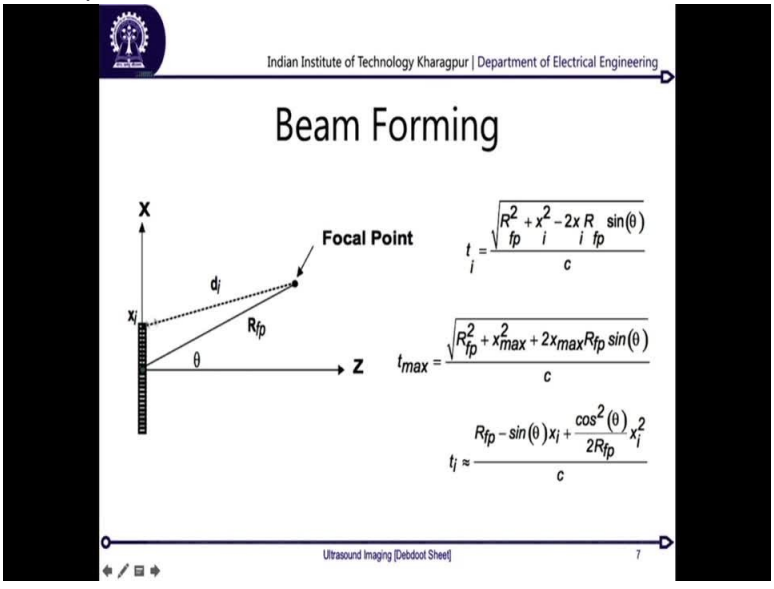

Now say that I have an array of transducers which is over here, okay and this is the centroid of that center of the transducer. So from here any particular transducer is at a distance of xi, so my ith transducer is at a distance of xi and say this is the point which is reflecting my beam now, okay. So the distance from this center of the transducer to this point is called as Rfp okay and the distance of this point to this ith transducer is called as di, okay. This axis is x axis so which is along the length of the transducers array over there and the direction which is orthogonal to the length of the transducer array is called as the z axis over there.

Now, with this kind of a setting we would get that the time taken for a pulse to start from here and arrive over here is equal to ti. So a pulse which starts over here and strikes back at the transducer ith transducer which is at a distance of xi from here is given by this equation, so you can just solve this standard geometry and you will also be getting down the same sort of an equation coming down over here.

Now, look into one particular point that the distance from the transducer of this particular point is a constant factor that does not change with the elements of the transducer. The inter elemental spacing between the transducer is also constant, that is why you you actually know what is the distance between the center point and every single ith transducer which is also constant.

The only point is that if the scene which is also the sound of the speed of sound in that particular media is also known to you then you can always solve this one out and now you will know that from a particular point in space if I have a reflection then at what time intervals it is going to reach which particular transducer over there. Now from there we need to have another estimate which is called as the maximum time taken down to for this wave to reach down from the first transducer to the end transducer which is the total scanning duration which we need to take care of.

So if I am looking if I am scanning for a larger interval of time what would happen is that say there is a point over here and that so by the time I finish scanning this one, the beam from this one also strikes this one. So that is going to create some sort of a ambiguity between the two points which I can discriminate and this factor as such is very much important in order to decide the spatial resolution of your imaging instrument.

So from here x max is basically the maximum distance to be covered over there. Since that is also known for a definite transducer geometry so you can always find out what is my t max. And this t max inverse of this t max is my pulse sequence repetition time which will give me that for like after this amount of time I should be sending my next pulse and wait for the next object to come down on being imaged.

So together if we look into this whole concept over here and try to even reduce it in terms of this theta because that makes it even an easier job, is now you do not need to know what is this di and what is this xi's and everything but you just say what is the radial distance between the point I am trying to look from my transducer center and what is the angle at which this particular thing is located.

So now you have way in which you can actually do a sweep in the angular direction and find out different points located along that sweeping array over there, okay. Now this is the way in which imaging is carried down. Since we are not a class on details of imaging instrumentations so we cannot go much beyond this except for understanding that is basically over time you can discriminate it out then you are able to create down in space where the objects are located and that is the basic principle of ultrasound imaging.

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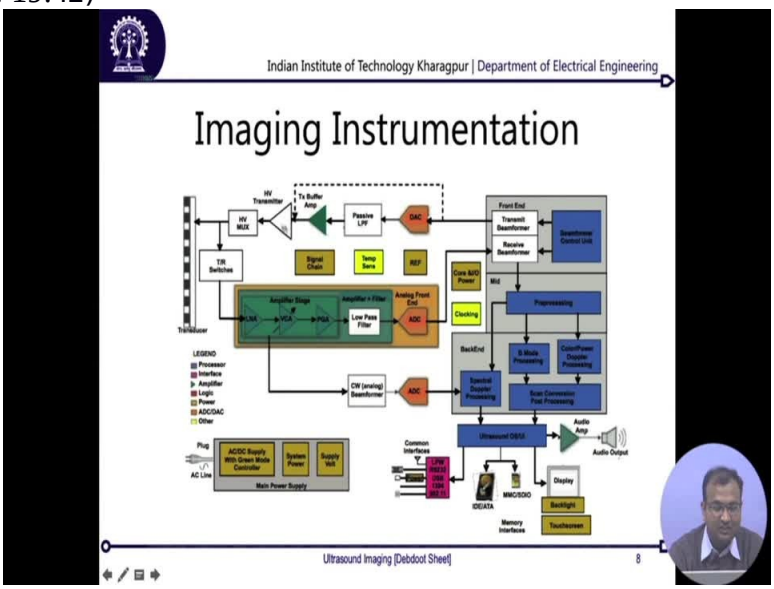

So this is a basic block diagram of what an ultrasound imaging instrument looks like, so over here we have the transducer, okay. And if you look at the transducer there is a multiplexer over here which has a transmit buffer and there is a receive buffer two sides of it, okay. Now what this multiplexer does is that it basically switches whether you are sending a transmission beam or a receiver beam and then if you are in the receiver mode you do not switch on the transmitter. Whereas in that case what would happen is that you are going to put this whole high voltage transmission into the receiver side and just kill up fry up this whole circuit over there.

So this is just to stop this one and over here we have the rear end or the back end over where you have rest of the post processing going on. So basically all transducers and all these readings over there are captured and sent over here, so in this part it tries to find out what is the difference between the repetition sequences coming down at multiple transducers and from there interpolates into where in space is my actually abnormality located or the actual reflector of ultrasound located over there which is pretty much which sums up the total principle of an ultrasound imaging system.

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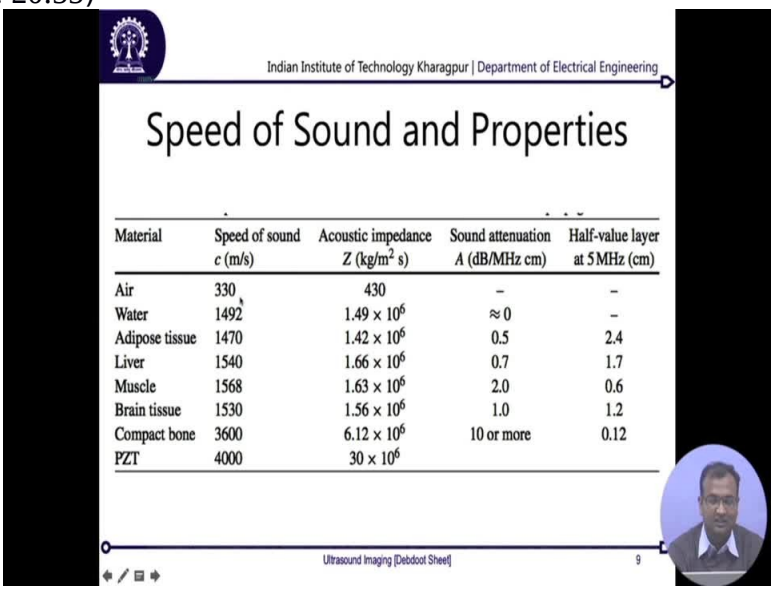

So some important things from perspective of understanding medical image analysis is to understand the speed of sound and property. Now one thing is that everybody often know about the speed of sound in air is 330 meters per second, okay? But as you keep on going into denser media, your speed of sound actually increases, in water it is 1492 meters per second, in adipose tissue or what is commonly known as body fat so something beneath your skin which keeps you warm is that part which is called as adipose tissue the speed of sound is 1470 meters per second which is very close to water actually it is just 22 meters per second of a difference over there which is sort of negligible.

On your liver, you have a much higher speed of sound and as you keep on going you would see that in compact bone it is the highest 3600 meters per second and this again concurs to our understand that in solids the speed of sound is highest and in gaseous media the speed of sound is lowest, okay. So from there analogous to the refractive index which we have for light, we also have an acoustic index and an acoustic impedance for different materials as well and this is a list of the different acoustic impedances.

And if you look carefully over here the acoustic impedance of air is much lower than all of them which have acoustic impedance in the order of 10 power 6 and that is the reason why if you like speak in air basically multiple eople can hear over longer distances. Whereas over here since the acoustic impedance is much higher so it will die much faster. So this is the reason why your depth of ultrasonic imaging is very much limited, you cannot just go for an infinite depth of ultrasound imaging over there, you have a very finite depth.

Because after some time you are just going to lose down all viable amplitude and will just getting down lot of noise coming to you, okay. so now another factor which you have to look is this half value layer so what this half value layer means basically is, when you are emitting a pulse from the transducer it has a certain power. So the power decreases to half of it at what distance. So this is similar to a half power distance or half power bandwidth you have for electromagnetic systems as well.

Now, if you look at it the adipose tissue has the highest distance of this half power distance, half value layer. Now, for this reason if you are imaging fat than you can image to a much larger distance without having much effective noise. Whereas, you would see that in muscle this is the

lowest is it is quite low and in compact bone it is the lowest. And so ultrasound imaging of bone is practically not possible.

So if you are trying to image down bone you would get a very distinct shadow after just touching the surface of the bone because most of it just gets absorbed very drastically in front of the bone.

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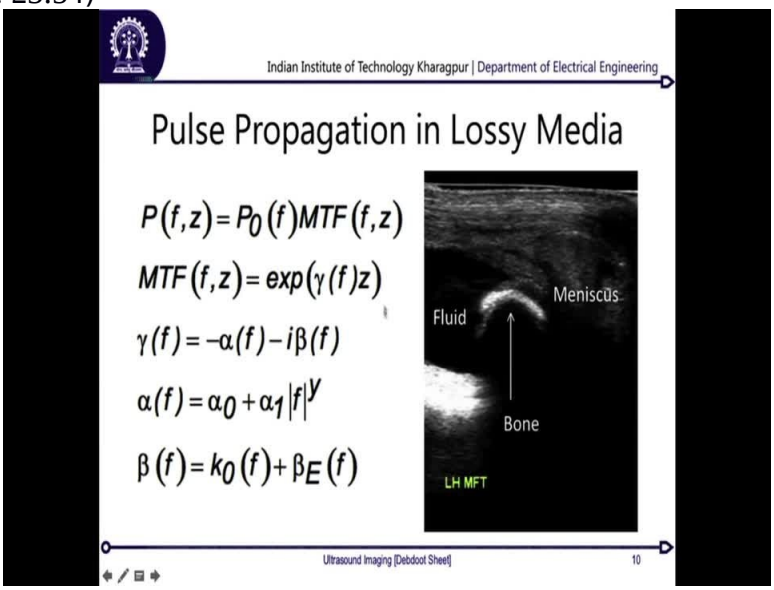

Now let us get into what happens with this so now that we had understood about all of those different properties and some numbers for tissues and how it works out I want to show you one of these images. So over here you would see that this part is this top part is the skin and then you have some adipose tissue and over here muscle fibers and then there is a bone. And now look interestingly over here you did not have any bone structure present, that is why you could go to a depth over here somewhere and you still have very viable speckles coming down from here.

Now when the moment you heat the bone after that you basically have a compete shadowing you do not get any more reflection back from there and that is called as a perfect acoustic shadowing over there. So this is in effect what happens when you look on the image which is a property of all the objects which you where trying to image over there so they are very characteristics attributes of tissue properties themselves.

Now, we define something called as the material transfer function while the wave propagates through an ultrasound and this is the relation between them. So what this says is that say P not of

f which is the power of ultrasound at a particular frequency so this is very much dependent on the frequency of that transducer you are using when it is being activated if that is P not and say at a distance z. So along this length is z which we had seen, okay.

So along this length at a particular point which is at a distance of z what is the total power received and that is a product of this one multiplied by this material transfer function. this material transfer function has two attributes over there the frequency and the z direction together. Now that gets defined something like this that this MTF is basically an e power of the factor gamma f times of the distance from the transducer and gamma f is again a complex quantity which is minus alpha f times minus alpha f minus i times imaginary times beta f and alpha f is again dependent on a constant factor alpha not which is property of this mass of tissue over where it is going.

So different tissues have different types of alpha nots over there and alpha one which is also dependent over here and alpha one times of frequency raise to the power of y, this is what it signifies over there. Now as you see that if we have a if we look through this whole cumulative set of equations along with alpha and beta you would see one particular thing that at the same depth if you have a higher frequency you have a (liv) larger attenuation, right?

So it is definitely always a very profitable to run at a lower frequency, right? But is that always a very good idea is the question. I mean if that is so then let us run it if I just want to use the best of the ultrasound frequency let me use 21,000 hertz or 21 kilo hertz the first ultrasound frequency over there. But when you go for actual imaging, you would see that most of them run into something of megahertz and that is where I will come down to this clinical use tally.

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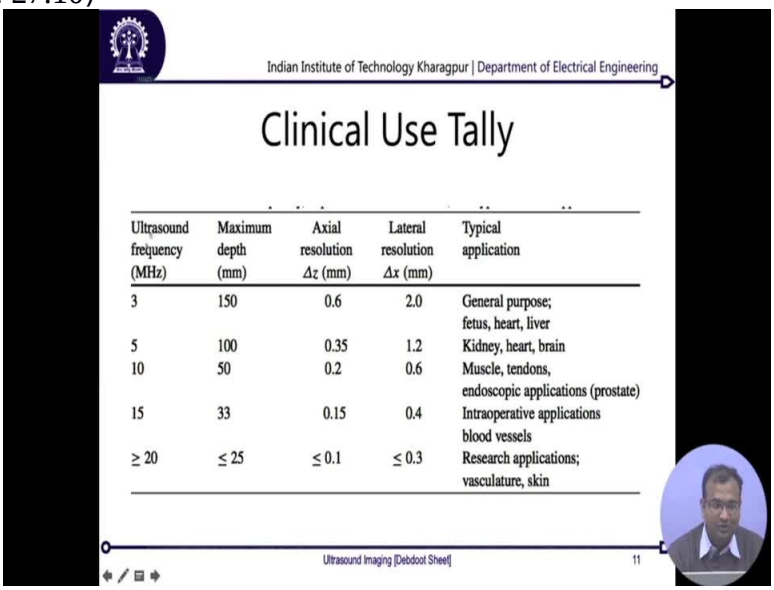

Now look over here that ultrasound frequency of 3 megahertz this has a maximum depth up to 150 millimeters obviously if you go to greater than 20 megahertz you have less than even 25 millimeters over there or 2.5 centimeters, so it is very beneficial to use a 3 megahertz in one way. Now the question comes down in the aspect of resolution which is axial resolution if you look at it if you have a lower frequency obviously you have a larger wavelength, so your axial resolution is also going to be lower over there.

So your ability to discriminate 2 neighboring objects along the z direction at a lower frequency is much lower, then you have at a higher frequency and that is why if you are looking at a larger depth you have a lower resolution, if you are looking at a smaller depth you have a much higher resolution and you compensate with the ultrasound frequencies as well. So if you are using a 3 megahertz probe you would try to look at a larger depth rather than a higher resolution in a smaller depth because you will never be getting higher resolution in any way.

The other factor is obviously on the lateral resolution as well because that also impacts which is along the length of the transducer how much was the resolution you where achieving and that is also again depended on the frequencies. And as you see that if we increase frequencies obviously your depth decreases maximum depth of imaging, but your resolution as well increases and based on that we basically have different organs which can be imaged with different frequencies of transducers and this is what clinicians refer to as a standard tally.

So 3 megahertz is for general purpose or fetus ultrasound, heart and liver ultrasound whereas 5 megahertz is for kidney heart and brain and that is again looking at what is the depth and what is the resolution I would need for looking into my pathological structures over there. So from there 2 frequencies of 20 or greater than that are most for research applications and for vascular and skin applications.

So there are particular imaging modalities called as intravascular ultrasound where you use frequencies higher than 20 megahertz something like 40 megahertz or 63 megahertz which offer a much high resolution but for a very smaller depth because depths of arteries or the thickness of arteries is much smaller actually.

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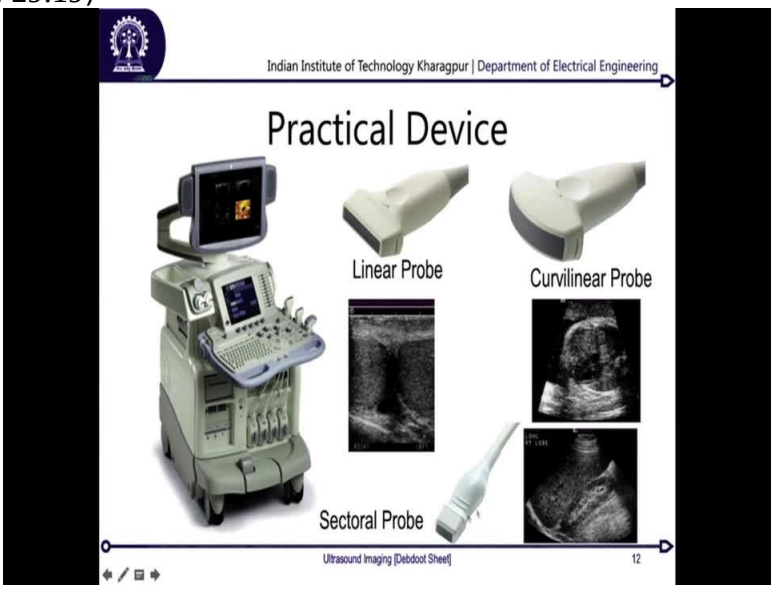

So let us enter into a very practical device. So this is what if you are there at a clinic you would be looking at an ultrasound and this is what it appears like, so this is where the clinicians sees all of this, this is a standard keyboard for entering the data of the patient over there, these are three different probes and these are of its some controls and on including on this touch screen which basically control where the person wants to focus and what are the different types of frequencies they are selecting for each of these probes and multiple of these control parameters which are available over there.

Now, typically with a linear probe which look something like this you would be getting an image of this sort, so keep one thing in mind that here it is linear so all the waves are going exactly so the beams the waves are not going orthogonal to it but the beam formation is always orthogonal over here. So you would get down a perfectly linearly looking image coming down over here and these are more of use for like imaging of say the carotid artery and similar very close to surface very vascular structures.

The other one is a curvilinear probe which is very common of abdominal imaging and for imaging of the liver and on this curvilinear probe what happens is since the surface is curved you can actually make out that the beam which goes orthogonal to the surface points will also be spanning out over a region over there and it forms a very curved region. Now the other kind of a probe is called as a sectoral probe which is very much useful for cardiac imaging and what happens is the probe is very small over here and again it has a geometry which is almost like a curvilinear probe but even with a much wider span than a curvilinear probe over there.

And since the size is very small what it helps is if you are trying to do cardiac imaging you will you have your ribs over here and you will have to look in between the ribs, so now this probes dimension is much smaller so that you can actually place it in between two ribs and you do not get enough of acoustic impedance coming due to the bones of the ribs and you can look through all the structures present inside over there. So these are some of the commonly used probes which clinicians use and most of the data and images you would see are from these kind of probes over there.

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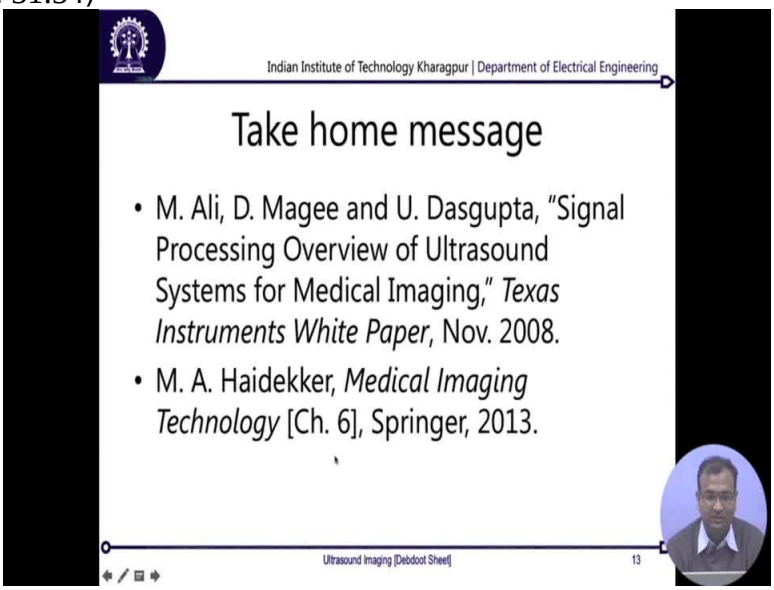

Now for much more detail reading you can actually have a look through this particular white paper from Texas instruments which discusses the whole signal processing overview of ultrasound systems and as well you can look into chapter 6 of this particular textbook and medical imaging technology which discusses about the actual instrumentation, the clinical attributes and different properties of ultrasound in total. So with that we come to an end to ultrasound imaging and thank you.

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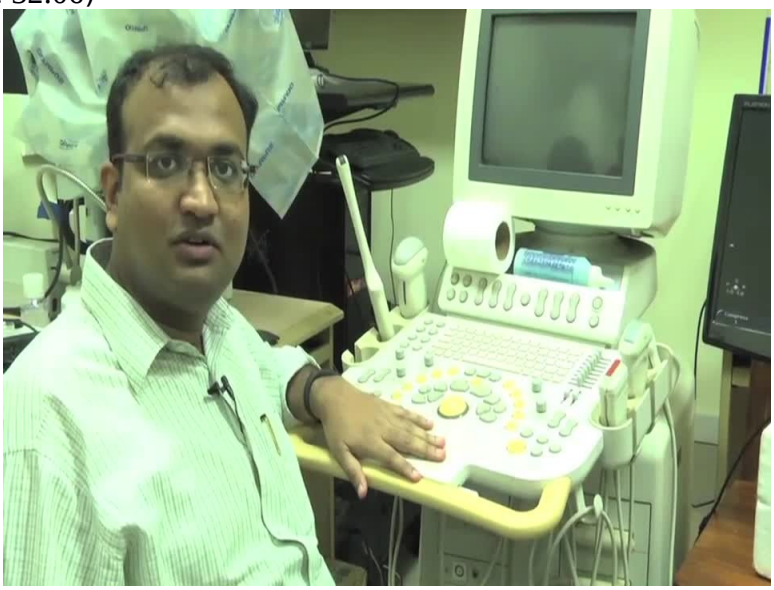

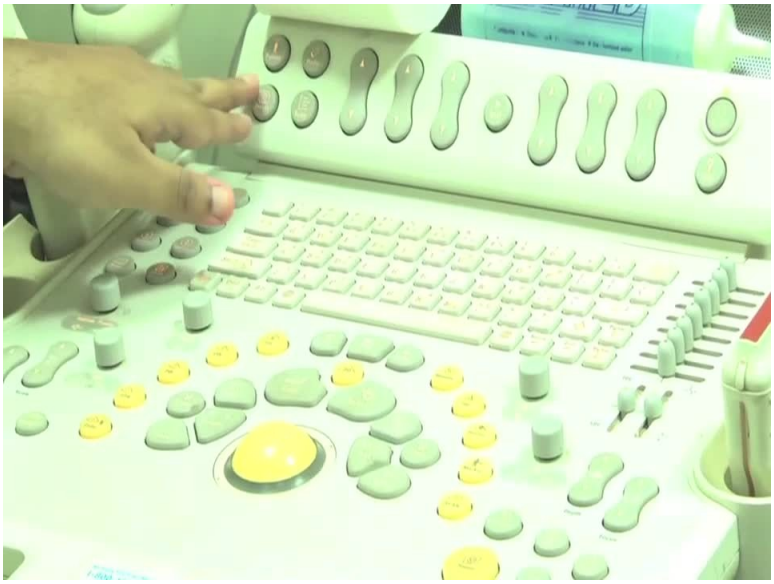

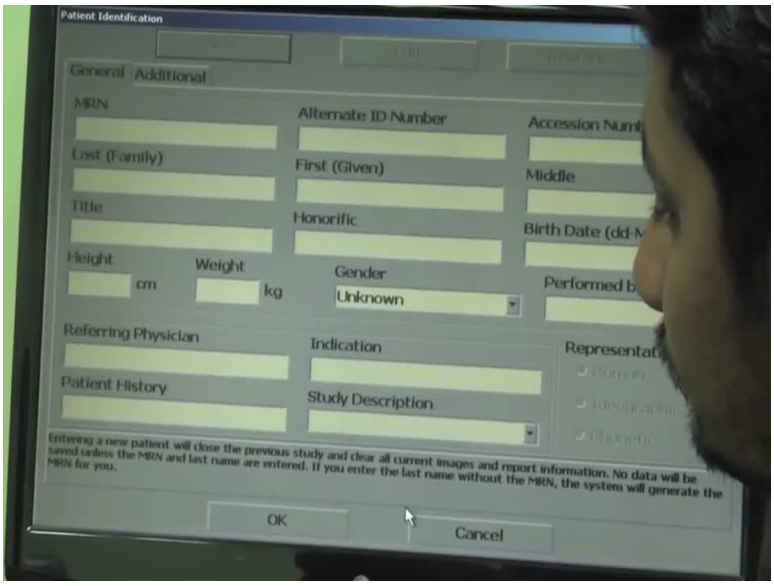
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Indication
Patient History
Study Description
Entering a new patient will close the previous study and clear all current images and report information. No data will be saved unless the MRN and last name are entered. If you enter the last name without the MRN, the system will generate the MRN for you.
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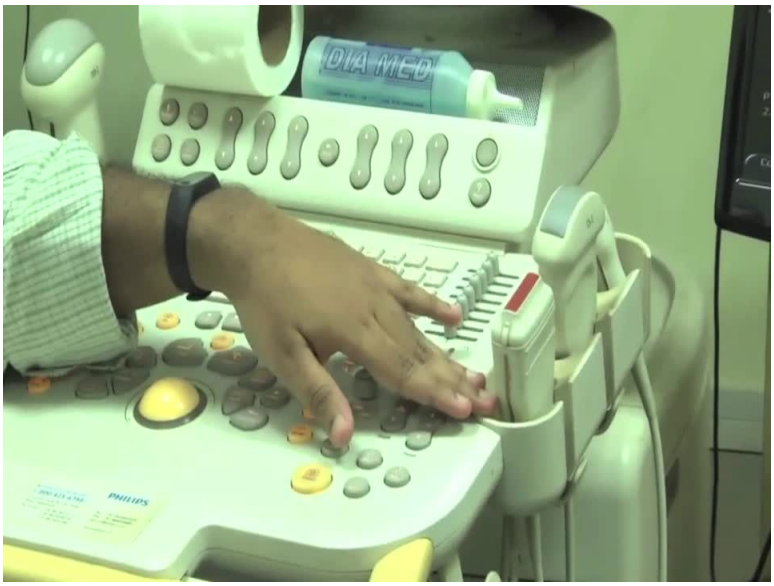
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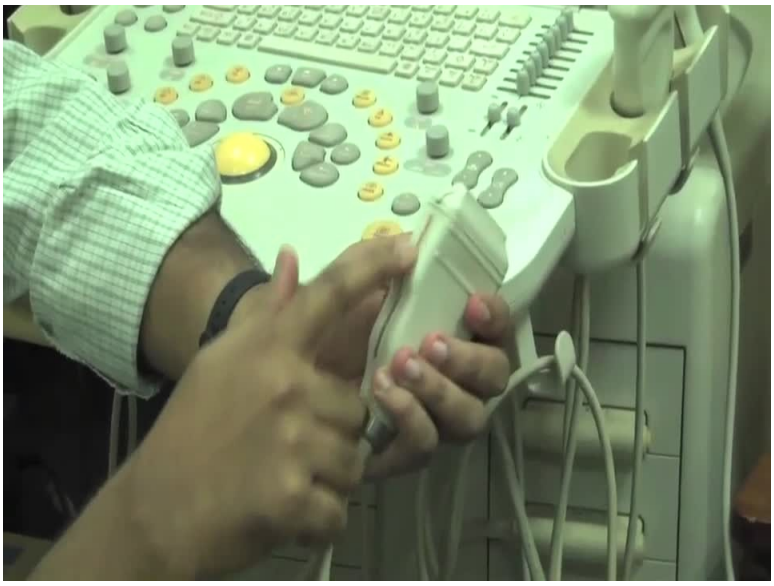

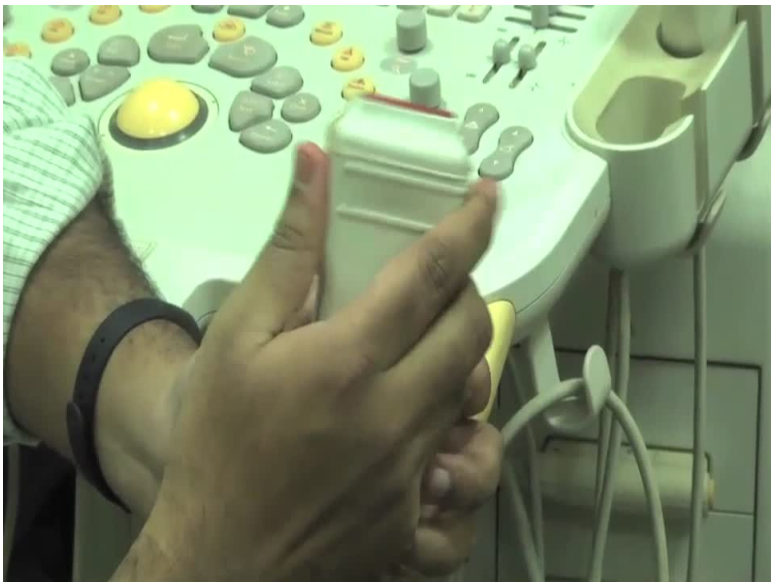

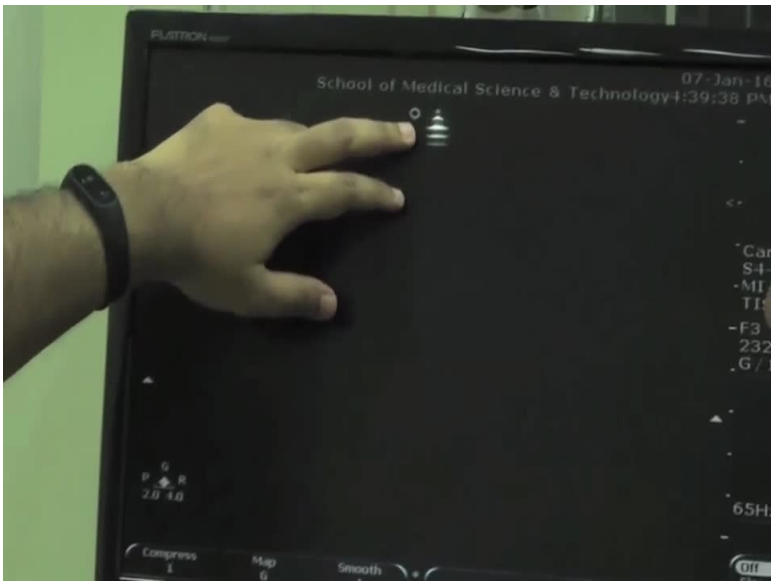

Okay so today I am going to show you basically a demonstration of one of those practical ultrasound machines and you have already seen something similar to this particular image on the presentation which we were doing for ultrasound imaging. Now to give you a closer look you have a keypad over here which is a quite a generic keypad and the purpose of this one is to enter all textual information which is related to the patient.

So I can just click over here and start up a patient's session and if I want to create so I will just go over there and create a new patient and enter all of them and then click on ok and then the patient information gets saved over there.

Now for as for the rest of the things you would see that there are 3 probes over here which we are going to use and they are pretty similar to the ones which you have seen on the presentation as well. So the first probe which I have is a linear probe, now if you look carefully over here there is a marker and this particular marking is basically my left reference or the reference similar to what you see over here as a circle.

Now on the screen if you see this particular circle is always aligned onto which side I am holding my particular probe over here, so since it is on the left so I am supposed to hold my probe on the left so that I have a perfect (())(33:27) reference. Otherwise if I just flip it down then it will be a reflected one coming down over there. So there is also a way of basically changing it out so there are options of basically reflecting out the same probe over there without much of an issue.

Now one particular interesting thing I would like to show you is the number over here for this probe so this L123 which means this is a liner probe of 12 megahertz and this 3 is basically a number which specifies the generation of iteration of this particular probe which was under development.

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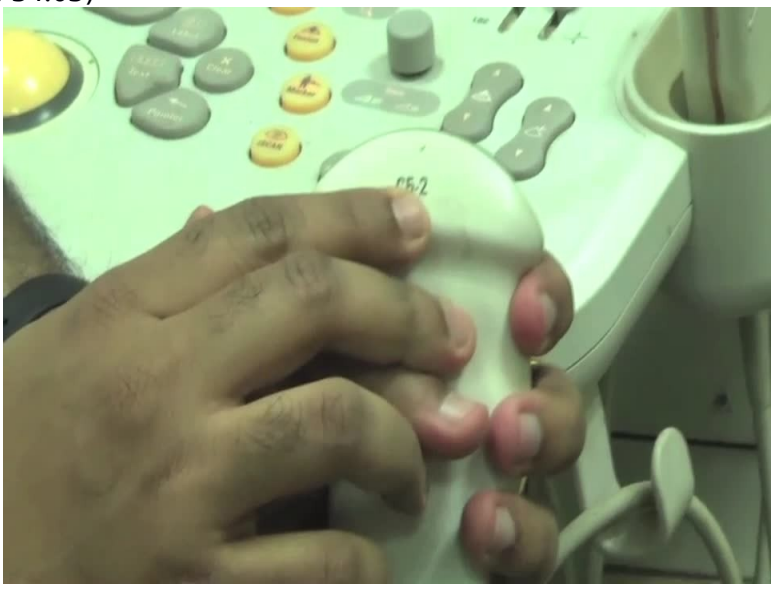

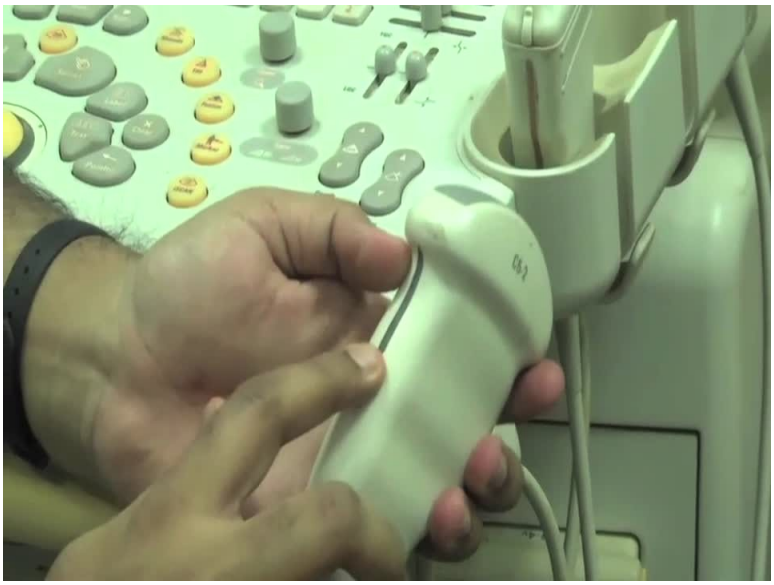

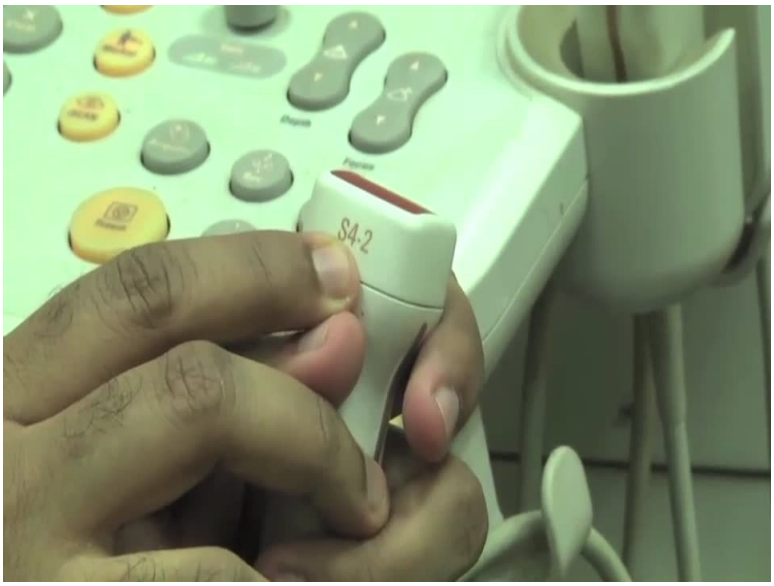
S4-2

The second probe which I would be showing you is a curvilinear probe there is a C52 so this is a curvilinear probe at 5 megahertz and the second generation of that particular probe and you have a similar notch over here which signifies left side of it and it is quite an ergonomically designed one so that you can hold it very rigidly in your hand. Now the other probe which we had seen was a sectoral probe for cardiac imaging so this was a S42 and this is a sectoral at 4 megahertz and the second generation of that particular probe over here.

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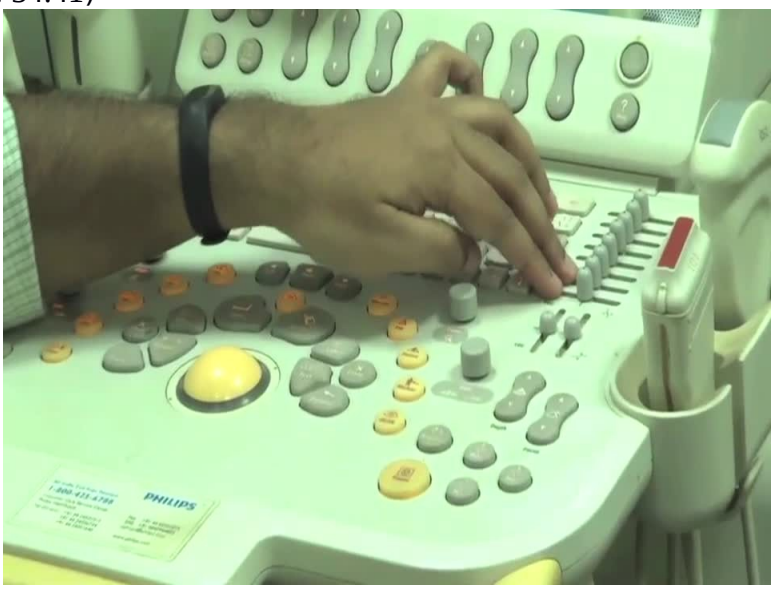

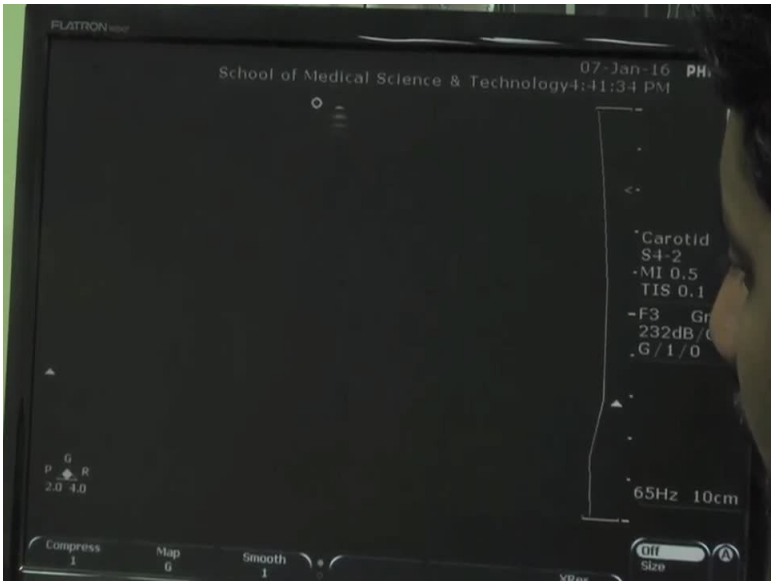

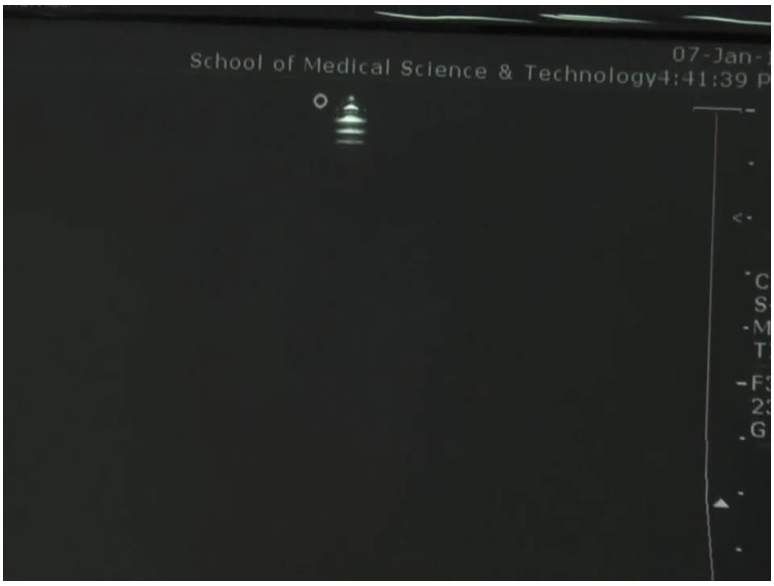
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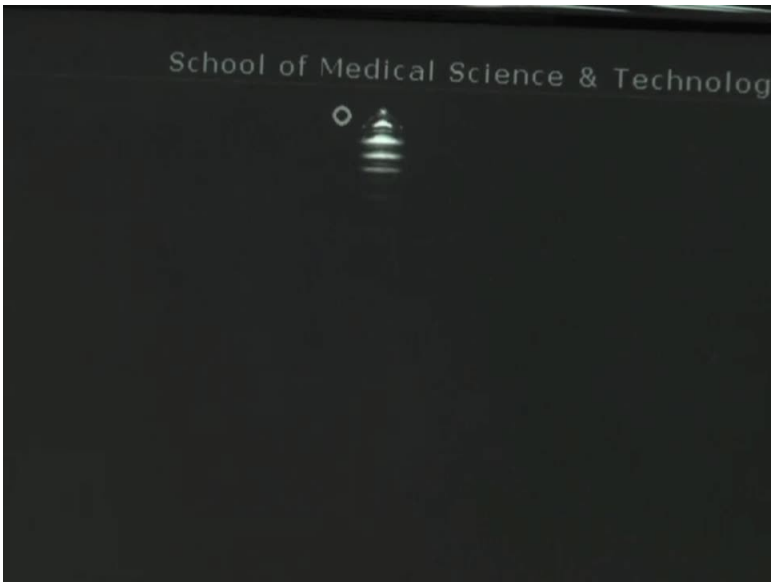
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Pg Up
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Zoom
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Gain
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Now some other controls which you can see up on this particular control panel over here the first one is called as a time gain compensation now since ultrasound as it propagates we have look through those equations and the total derivation as to how the energy actually attenuates as it goes to a deeper tissue. Now for that particular reason you will have to amplify signals coming back from much deeper down, then you have to amplify the signals. So basically you need to attenuate signals which are very close to you and sort of amplify signals very far off from you.

So if you look at that screen over there you can see that as I keep on changing these parameters there is a gain factor which is changing shown as a curve over there. Now this is generally we do not make any changes onto this one other than the radiologist who has a very subjective jurisdiction onto making these changes over here because the machine is pre calibrated and systems are preset over there as to how to use it. The other one which I would show you is called as LGC or lateral gain compensation, now this is something which compensates the left right kind of a loss over there so say that I want to amplify the signals which are coming from the left hand side and I want to attenuate signals coming from a right hand side so I can basically make those changes over here.

In general we keep them as unity amplification of both sides and only in very specific cases that we use very selective amplifications coming down over there. Now without taking a much of a time, what I would try to show is one of these probes and how we are doing. So we have our

volunteer over here Devargo who is interestingly doing his PhD also on ultrasound and today we are going to perform an ultrasound on him.

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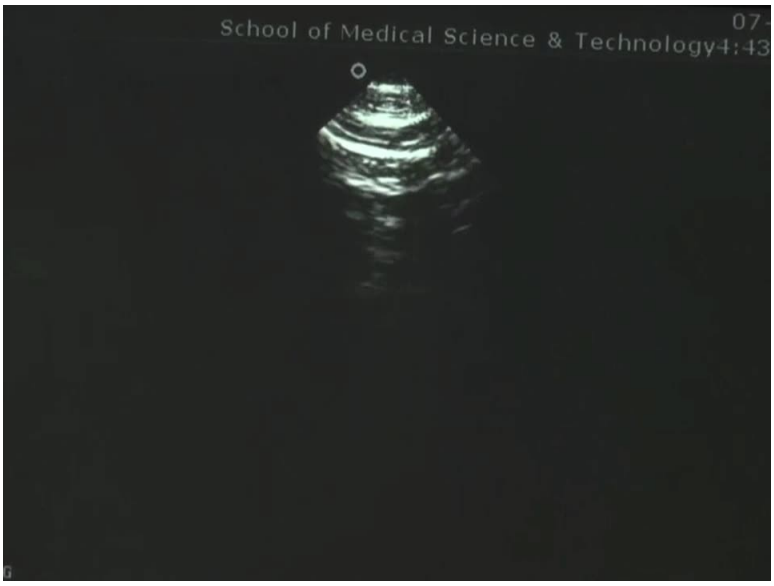

So he has volunteered to have his carotid imaged, now you can see as I (pu) put up this gel which is basically just an conductive sonologically conductive gel. So this is nothing other than some gelatin and water and some preservatives mixed together and is perfectly nontoxic for external use although like it is never suggested that you still try eating it because it is not an edible product as such.

Now as I put this one you would see that there are speckles which becomes very stationary over there on the screen which where earlier not appearing before I put down this jelly and the reason for them is that the sound which is coming up from the probe it is passing through this jelly over

here and then trying to come out but on the top it is basically air which is much rarer in acoustic density than the gel itself and that is causing a lot of reflection.

So these are basically subsequent stationary reflections which are going down within the jelly itself and that is causing those kind of stationary speckles appearing on the screen. So let us try to put them into a actual clinical use so let us look into the Devargo's carotid artery now if you see over here you would see a beating structure, so this particular structure over here is the carotid artery.

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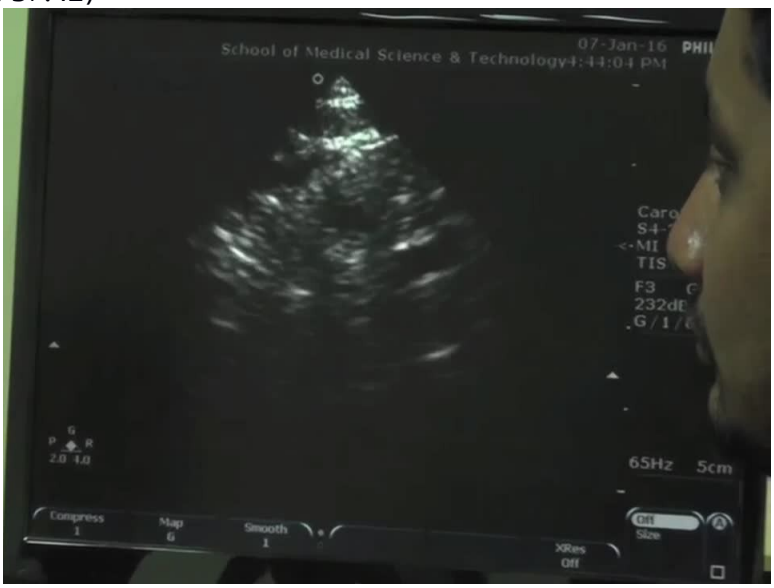

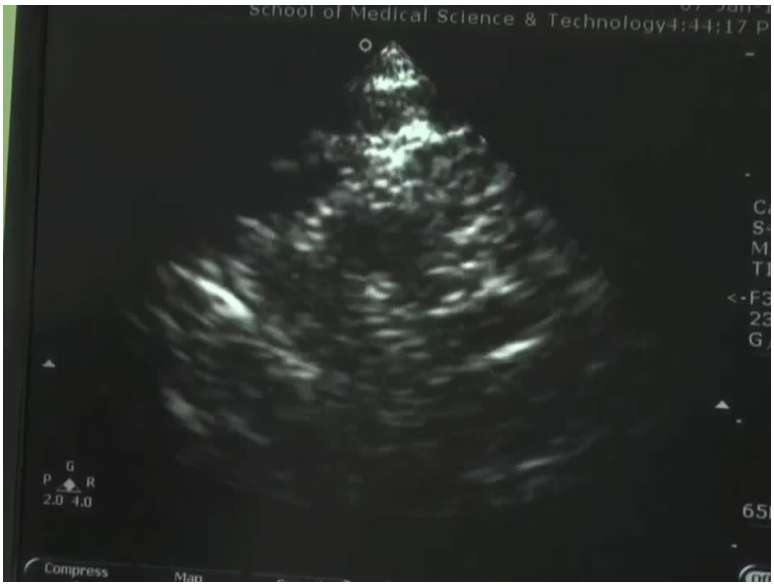

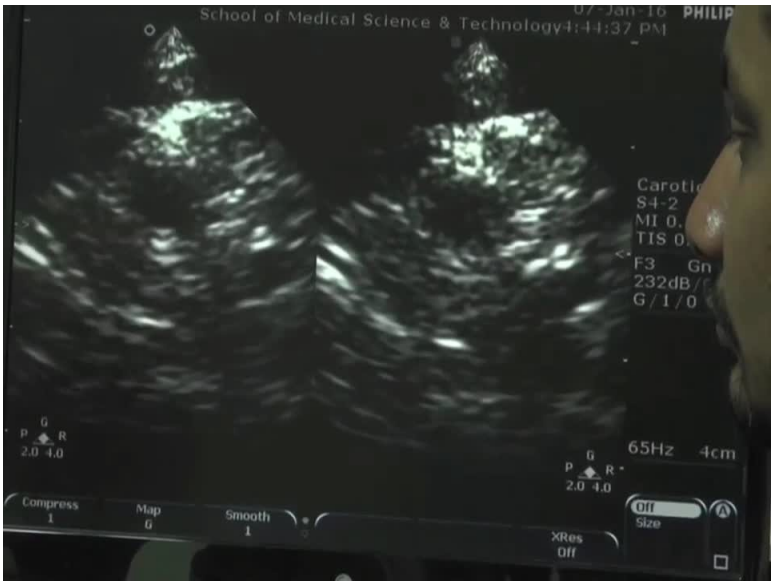
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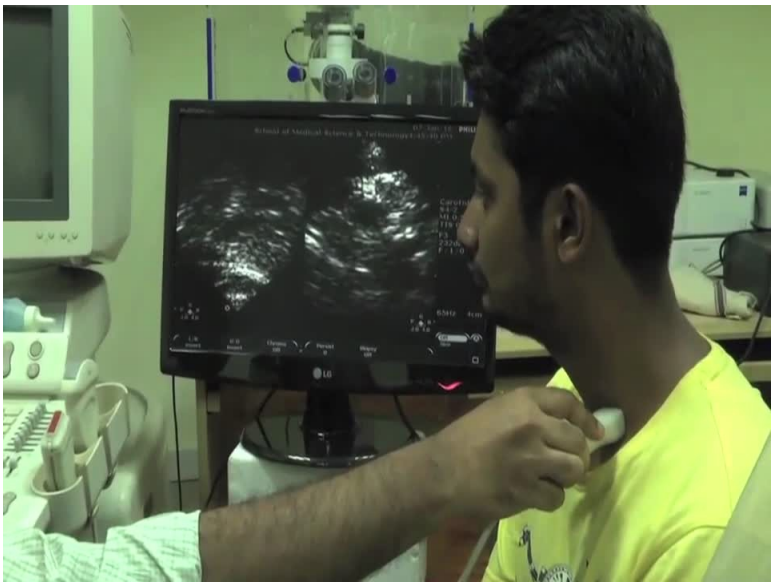

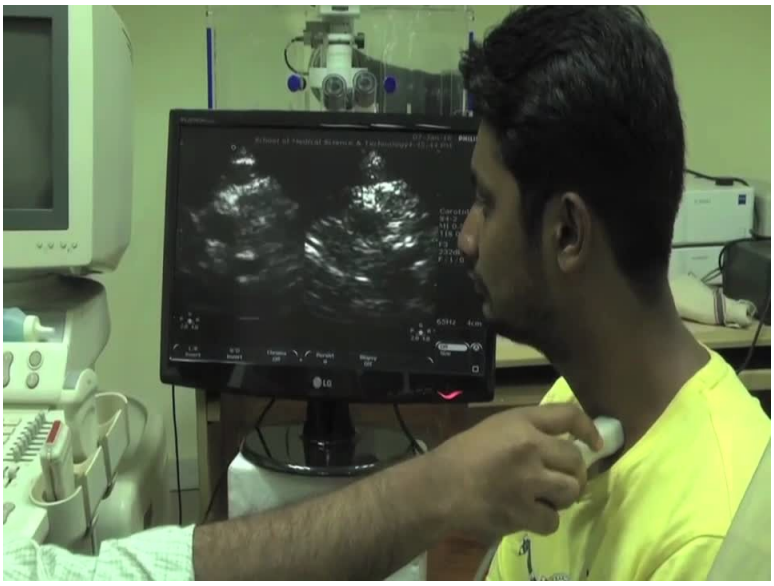

Now let me actually try to zoom over there so what I would do is basically I reduce my depth of scan so that you can see a much better view over here, so as I reduce my depth of scan you can see it now I would try to change my focal zone as well but somehow it does not allow me to go any more deeper in focus.

So this is the carotid artery which is beating there over there, now interestingly you can see that the speckles are really large over here, it is in the order of like a few speckles like few tens of speckles that the whole carotid artery would be seen. Now let us actually freeze this one, so what I would do is I would put it on a dual monitor. So you can see this is one of the frozen views from this sectoral probe and this side is my dynamic view.

Now we have some basic systems settings which we can change over here. So I can change my map over here. This is a grey scale intensity mapping function which maps non linearly maps intensities received ultrasound echoes two intensities. Smoothing is something which is a frame averaging which is good for actually reducing the total speckle heterogeneity over there, but you eventually end up losing a lot of information.

Persist is a moving window average kind of thing. So if you have a larger persist than it will keep on having lesser speckles but again you compensate on them. And this LR invert is what is inverting my reference. So if my reference is like this and I want to invert it out than I can use

my LR invert over there to have the same thing and similarly you see there is an up down invert option over here so this will do a vertical flipping of my image as well.

Now let us move from one of these probes so as I finish of I am going to wipe off the probe as a standard practice and precautionary measure and next I am going to use this curvilinear probe. Now for that I will have to do a hard switch within the system because all my driver circuits over there, my amplifiers, my power drivers everything will have to physically switch over to another probe which is electrically connected over there.

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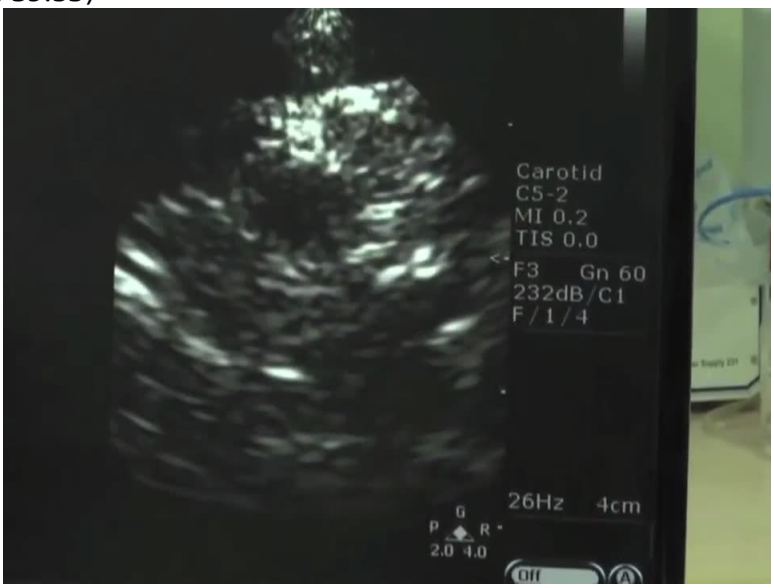

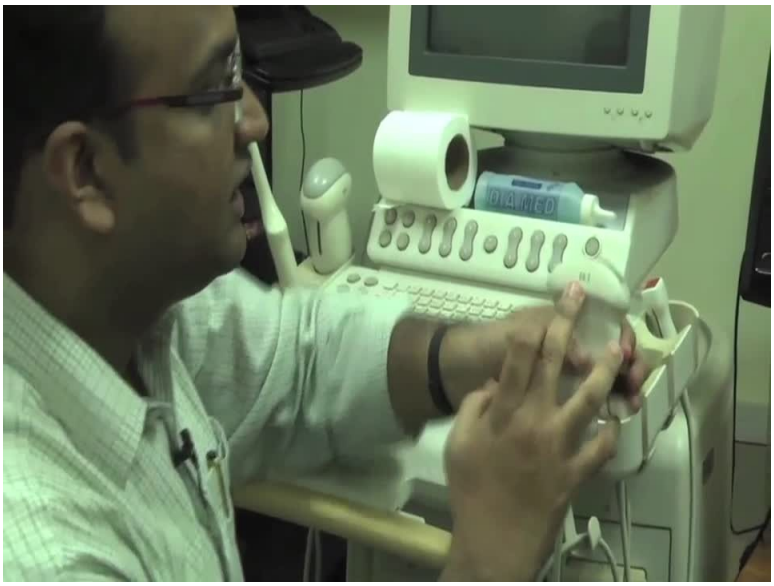

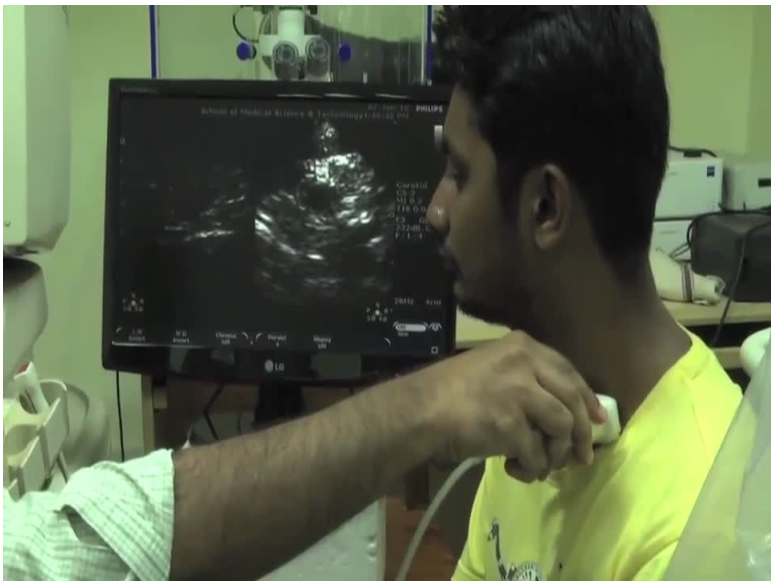

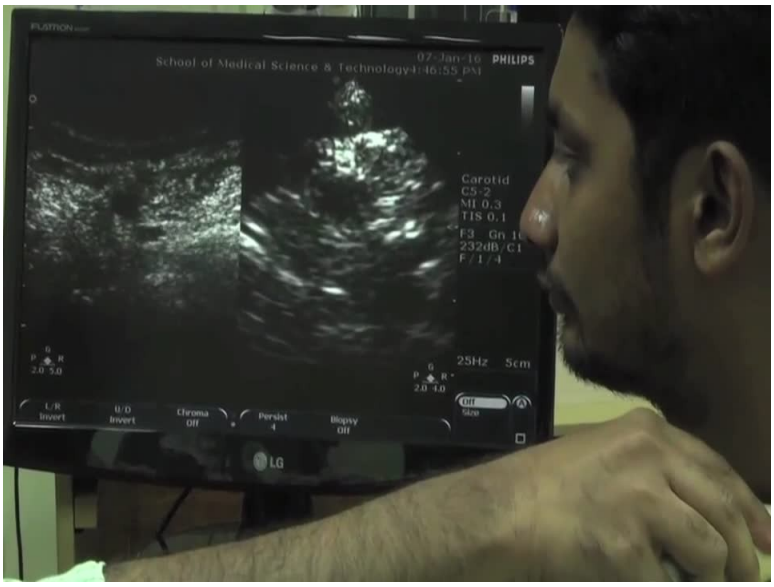
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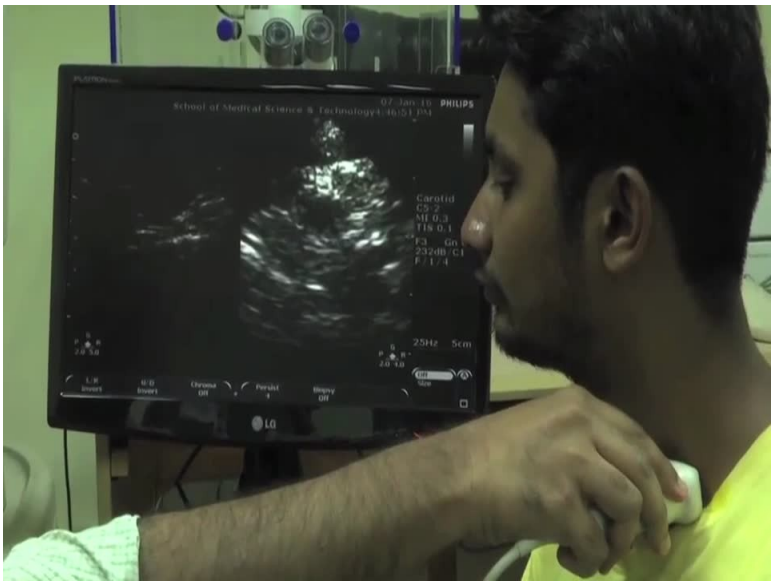
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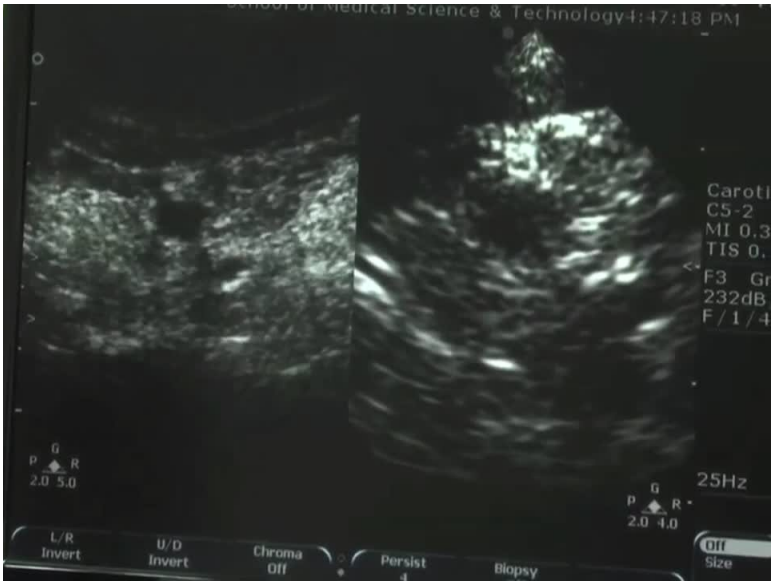
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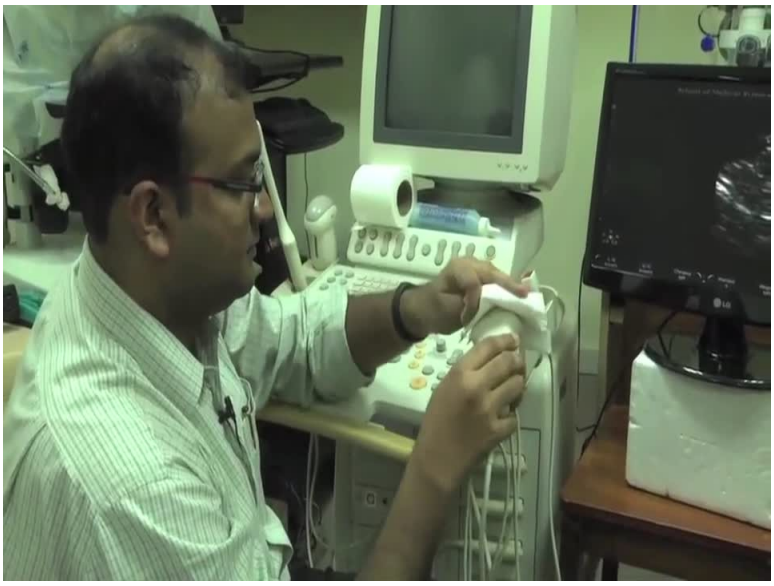

So I have my switch over here we just called as probe, there is a probe flipping switch. So I switch over to that probe next probe over there and if you carefully look at this probe, this is called as C52 and let us look over here on the screen you would also see the same probe, so this means that this particular probe is already selected, so it is my curvilinear probe which is selected now. Now I put down some jelly on my curvilinear probe okay and now let us try to image down the carotid artery over there.

So as I see I need to go down at a higher depth and possible increase my gain factor as well, and now I can see his carotid artery beating over here, okay. So I can zoom into that as well. So if you see together you would see that one interesting fact is that you we did achieve a higher resolution when we were looking into through this probe and that was because this is at a 5 megahertz rather than the other one which we were using at a 4 megahertz over there .

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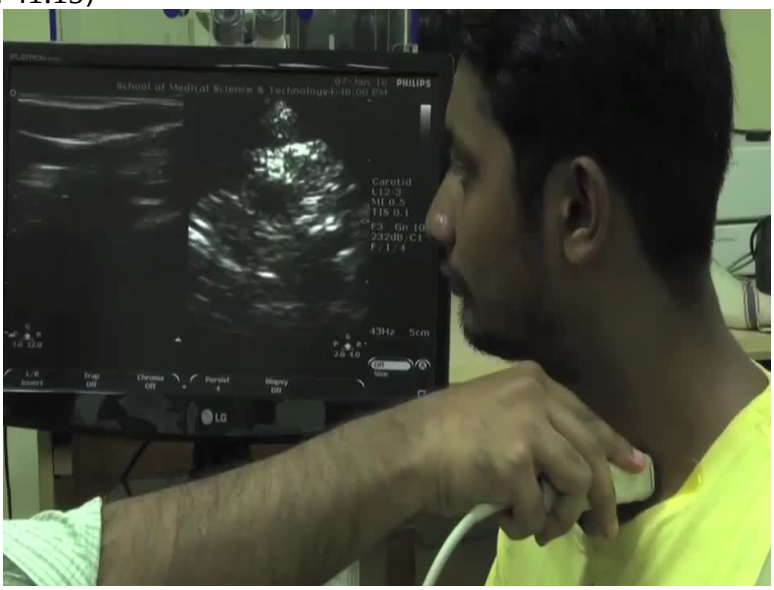

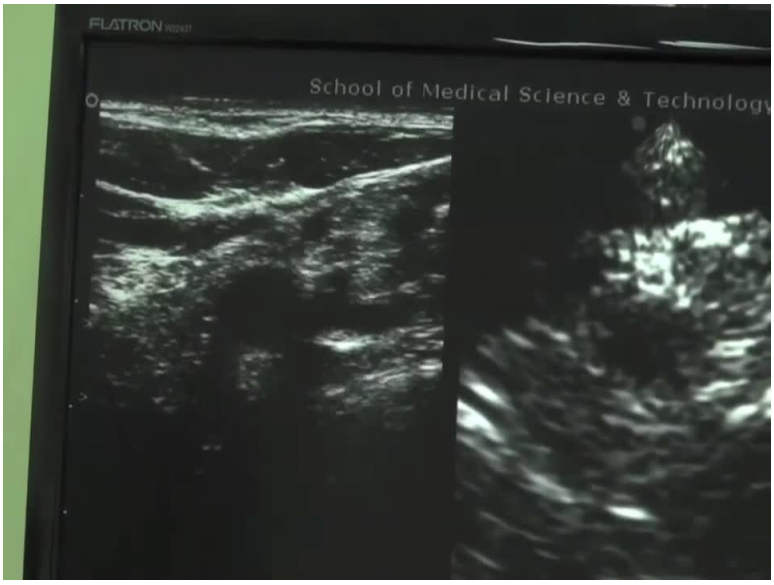

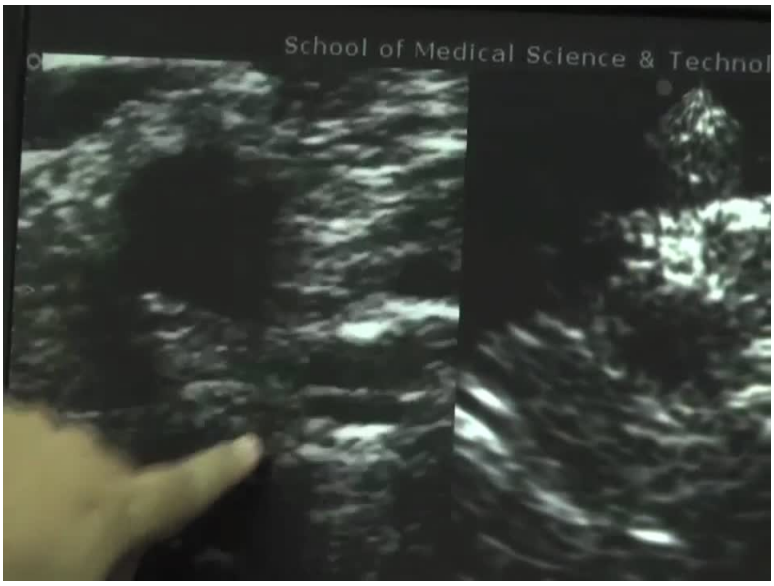
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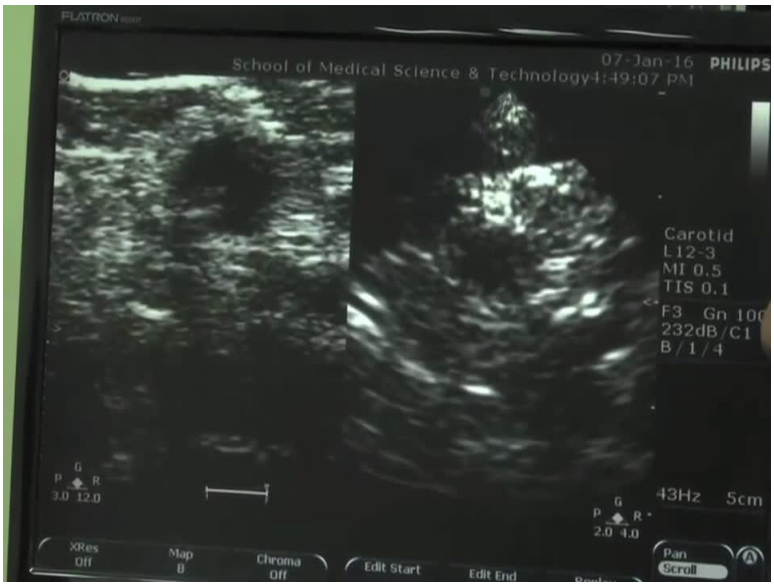
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So let me just keep this one back and the final one which is actually the one which we are actually supposed to use for imagining of carotid which is the linear probe which is going to give you the best resolution coming down over there. So I again do my probe shift operation and then you see it is a L123 which is corresponding to this particular linear probe over here and then as I put the probe so let us just do a bit of scanning through and I increase the gain I will have to change my mapping functions as well.

So here is the carotid artery which I see on the linear probe, okay now let us zoom into that. So one of these interesting things is you will see beyond the carotid artery this is where the artery is and the blood is flowing you see this enhanced region these speckles are much more brighter and that is called the enhancement, there will be a rim of shadows coming down over there which is clinically relevant and so one let us just freeze this one yeah so I have just frozen it out . So that is acquired the frame and just kept it over there.

Now if you look into the linear probe and compare it compare the one with the sectoral probe on the right hand side on those two images over there, something interesting is that there are much more denser speckles over here than over here, so the speckles sizes are much smaller so your resolution is obviously much higher you will get down almost three times higher resolution with 12 megahertz probe than you will be getting down with a 4 megahertz probe that is intuitive thing which you can do over here.

And so and since these where some of the intuitive examples which I can show down for our example and all of the images which will be having will be something of this similar sorts for processing and the challenges definitely in the presence of so dense noise over there and uncertainties how to do it and subsequent lectures we will be covering lot of these techniques as to how to specifically deal with speckles and whether speckles are seriously noisy and nuisance rather than something useful and we will have a case study where we will make use of this actual statistical nature of speckles as well. So with that thank you.