Neural Science for Engineers

Prof. Vikas V
National Institute of Mental Health and Neurosciences (NIMHANS)
Indian Institute of Science, Bengaluru

Lecture - 21
Brain Anatomy 3D - III

So, I do not know how much of the previous exercise was useful in the basal ganglia. The objective of the exercise was to give you a three dimensional idea of the structures and it is very difficult to show it in path. There are no models, 3D readymade models which show the anatomy in which I had shown you.

Because it as I told you it is a build and like you know all physical builds, you have to build it to actually demonstrate, what may not have been very clear is how these things are very close to each other, but that I would of course, be showing in several pictures and of course, operative videos in which these structures are very clearly seen. So, I will leave it at that.

Now, towards the last part of this story is this surface. Now, I had split up the demonstration, so as to say, into three parts; because a brainstem and cerebellum are single entities; there are features on the brainstem which are very closely related to the cerebellum and the cerebellum as such if you look has the least number of features when compared to both the brainstem as well as the cerebrum.

Now, in this cerebrum what is very easily taught and very popularly known as the surface of the cerebrum because a lot of work gets done over there, but unfortunately the deep grey is actually the more easier part of the story, but because of the structural complexity it is a 3D structure and you cannot simplify a 3D structure into one dimension less and be happy. It is not a lossless compression.

So, there is a limitation and that is the reason I went through the entire exercise of explaining how the thalamus is the central core and the other structures are draped over it. The direction of drape actually determines the orientation of the ventricles and the shape of the ventricles, the shape of the internal capsule. So, so many things are because of that topology of this structure so as to say.

Now, the ventricles if you start learning it in the routine fashion you have lateral ventricle, then you have third ventricle, then you have fourth ventricle and connected to the aqueduct of Sylvius. The lateral ventricle has different parts, and the third ventricle has different parts; the complexity of the parts increases from very mundane anatomy to very complex anatomy when you deal with neurosurgical.

Because there are several kinds of tumors which need to be accessed in the ventricles or through the ventricles. So, we need to be a lot more thorough with our anatomy as surgeons, but the same need not be for other kinds of medical specializations.

So, it is in the same spirit that I have not elaborated too much on the medical side of the story. What I wanted you to appreciate is how beautifully these structures arrange compactly and how in spite of their complexity they are fairly monotonous, they are topologically monotonous, unlike the surface of the cerebrum which is very rich and which deserves a separate understanding itself.

So, we are in the last part of the story. So, first part was brainstem cerebellum, second part was the deep grey of the cerebrum. Now, I come to the surface of the cerebrum and try to make an understanding of that. All of this stuff I would be explaining once again as the routine fashion with maybe photographs, writings and things like that which should you know if somebody is not appreciative of 3D anatomy can learn through the conventional fashion.

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So, this is a primitive. So, people who are in the animation space would know what a primitive is. So, I have just generated a whole brain primitive. So, it is a whole brain clay primitive, I created the primitive so that we build our understanding of the cortex based on that. So, I need to lift off the primitive from here. So, the cerebral cortex is somewhat like this. It is fairly an accurate representation. I will build the remaining structures as we progress further.

So, a major part of the cerebral cortex is this part which is the lobe part. Now, it is divided into lobes, we will come to where the boundaries of the lobe are; in general frontal lobe, parietal lobe, occipital lobe, temporal lobe and somewhere deep here is something called as the Insula.

So, that is the general architecture of that. So, there are two cerebral hemispheres which you have heard of, and I think we will continue with that understanding that there are two cerebral hemispheres and between the two cerebral hemispheres is a interhemispheric ridge.

So, the interhemispheric ridge for all its name is not a complete structure. So, deep inside the interhemispheric space is the Corpus callosum. So, we will look at the corpus callosum in greater detail later.

So, this is the corpus callosum, the two hemispheres on either side. So, now if you remember my discussion on the dura mater discussion you should remember that this space in between the two hemispheres is what is occupied by the falx cerebri. The falx cerebri is between the two hemispheres and it is sickle safe for that reason that it is accommodating the corpus callosum.

So, that is the corpus callosum, and my hand sort of represents the falx. So, that is how the falxes arrange. Now, between the frontal lobe and the temporal lobe is a very important structure called as the Sylvian fissure.

So, the Sylvian fissure is important because it sort of divides the temporal lobe and more important than just dividing the temporal lobe, it is important because it demarcates several things. So, both sides drawing. So, we first started with what is called as the interhemispheric fissure, next is the Sylvian fissure. So, that is the second build. So, we have built two major places.

Now, what actually covers this interhemispheric fissure, and the Sylvian fissure is Arachnoid. So, arachnoidal membranes cover that, you remember that the dura is like this, there is a falx which goes behind below into the interhemispheric fissure, but it is just about that.

Now, what connects the frontal lobe and the temporal lobe across the Sylvian fissure is the arachnoid. So, now I hope everybody has a clear understanding of what these things are. So, Sylvian fissure, interhemispheric fissure.

Now, if we see evolutionarily this is fairly a constant feature from a very low, most mammalian brains and much slower organisms have similar kinds of brains in which two hemispheres are there hemispheres supply opposite sides of the body both sensory and motor ok.

Now, this is front this is back anterior, posterior, superior, inferior, medial, lateral. So, that is the nomenclature which I wanted you to remember, and I would be using it several times. Now these fissures are so called complete fissures because when you reach the bottom of the fissure you find the corpus callosum.

Here you would find the insula deep and the brainstem if you go from here; these are popular surgical approaches. So, that is how we operate on the brain, the brain is you know you cannot operate randomly into various parts of the brain; obviously, important regions are there.

It is a major part of the surgical endeavor is in ensuring a traumatic or minimally traumatic access procedures to the brain. So, that is that is how we do. So, Sylvian fissure is here, interhemispheric fissure is here.

The next important structure which needs to be highlighted is something called as the Central Sulcus. So, the central sulcus is something which starts from this side of the brain and curves anteriorly somewhere up to there.

So, parallel to that is something on the opposite side. Now, you should remember that these are very deep fissures, deep in the sense that many of the say yesterday's the prior days in one of the prior classes I had shown you sulci and gyri and it looked like all sulci and gyri are similar to each other it is not so. So these are something called as complete sulci. So, they go very deep and may reach up to the no of course, the motor cortex central sulcus does not reach up to the ventricle.

Now, this particular step is also very important because somehow the brain has thought that it is relevant to preserve this kind of framework across a large evolutionary para this one. So, very large organism's elephants, whales, small organisms have this idea that there is a central sulcus.

Now, see remember I when I described sulci and gyri, I had highlighted the fact that is the gyri which is important, but if you look at evolutionarily it somehow the brain thought of conserving the sulci. So, sulci are deep structures which are very important say for example, Sylvian fissure interhemispheric fissure they are very conserved they are not they do not get disturbed too much.

Central sulcus is the same it differs from person to person. So, maybe across the same person, but it is there. So, characteristic of the Sylvian fissure central sulcus is it starts from the midline.

So, starts from the midline goes all the way up to the somewhere near the Sylvian fissure. So, I think my sylvian fissure is a bit too big here. So, I have closed that, and we have the central sulcus. Now, demarcation of the central sulcus is important for understanding a lot of things about the brain.

The central sulcus is called so because it splits several functional regions of the brain from each other. So, what is in front, anterior to the central sulcus is the motor part and what is posterior to the central sulcus is the sensory part.

You know when we say motor and sensory you should remember that motor consists of a lot of hierarchies, not just about you know moving muscles, but also about the generation of functions which help in generating smooth activity also in sequencing the motor activity.

So, when I plan to lift this instrument it should not be that my finger first moves and then reaches the instrument it should be in the correct order that you know it is a low level task it is still a low level task; I am just picking up an instrument, but that planning which is required for that first you go reach the instrument hold appropriately, meaning that is judgment right. You cannot pick up with the sharp end of the tool, you are not supposed to pick up from the sharp end of the tool.

So, that is the judgment part of the story and then grasp it with sufficient force neither to break it nor allow it to slip past your hand. So, motor has a lot of subcomponents in it. So, that part of the subcomponents is they are generated anterior to the central sulcus. Posterior to the central sulcus is similar thing, see I have seen the instrument which is in the occipital cortex which is way back occipital is behind.

So, occipital cortex is way behind, that is vision, posterior part of the temporal lobe has speech areas, the highest speech areas which in turn this is the left side of the brain. So, this goes to something called as Wernicke's area which is over here, we will come to that.

So, that is the higher comprehension level. So, you hear stuff, you see stuff, Wernicke's area is the sensory integration higher level center. So, there are layers of computational complexity; each region handles a particular level of computational complexity and like in neural networks very large GNA, GANS and CNNS you would find that downstream.

You know if you look at the analytical waves in which you find out what is being generated at the last but one layer where you calculate the output. You would find that those neurons in ANN are not influenced by say some small change in color or texture or something like that. They get changed by very very specific entities.

Say I have heard that some in between some neuron is sensitive only to a change in shape of the line or shape of a curve. So, there is a hierarchy. So, speech is somewhere over here left side and the higher center is over here Wernicke.

Similarly, the vision is somewhere in the back this is the occipital lobe and from there you got the higher association areas touch, touch is incidentally over here. So, these the sensation of touch and the higher modalities of touch are somewhere over here, and these get integrated with the Wernicke.

So, this is this whole part is sensory and this whole part is motor and that is the beauty of the system, these are very high level architecture. So, there is a lot of stuff which gets computed along the way in these different regions of the brain.

So, if you recollect this so called 5 percent theory, it does not hold water because you know we do understand that it is not just 5 percent of the brain which is working at all points of time. So, there is substantial amount of information processing, transfer, compilation, learning, memory retention and even read you know you pull back from your memory you know I know I understand that this instrument I picked up with a certain amount of force last time.

So, that memory is there somewhere it is not that every time I pick up an object like that, I anticipate you know I do not need to train on it right. So, it is there somewhere in my memory, some of it in incidentally maybe even genetic. Genetically I am programmed, ok it looks like wood. So, the weight of this object would be somewhere in the range of wood, you would not expect it to be of titanium or some iridium or something like that.

So, there is a lot of memory which, I have never seen those heavy metals. So, maybe you know there is a component of that also. So, coming back to our discussion here. So, we finished Sylvian fissure and then I finished the central sulcus. Now, what happens anteriorly is, this gyrus is one of the biggest gyri around and it has some stuff around there and then it comes it does not come up to the center. So, that is how you identify the motor cortex.

Now, the second method of identification is there is one sulci behind, which results in a relatively smaller gyrus. So, this is motor, this is the sensory cortex. So, that is how you understand how these things are. So, central sulcus motor cortex in front because motor areas are front sensory cortex, sensory areas behind.

So, similarly I have to have a big gyrus here reaches up to the Sylvian fissure, but generally does not go into the sylvian fissure and does not reach into the midline. This has important applications even when you do many kinds of research. So, motor cortex, sensory cortex, precentral sulcus, supplementary motor area. So, that sort of completes the easier part of the story everything is easy, but you know it is just that you need to understand things.

Now, you look at the motor cortex from top to down, there is an inverted representation. Now, this inverted representation business is very common across the several parts of the brain, we will come to more inverted stuff around. So, I spoke to everybody about localization within the brain and talk about how some area is connected to some particular function.

Now, this entire strip called as the motor area is connected to individual parts of the body. So, they do not code for individual muscles, they code for large regions. So, for example, this part is connected to the leg. So, leg as in the whole leg whole lower limb.

So, whole lower limb is somewhere over here, there is usually a bump around here which is the hand area. So, hand area is somewhere over there. So, hand is down, leg is up, face is somewhere in between and in fact, just in the region of the hand area is a fairly large area. So, this description of localization in the motor cortex of individual regions within the brain is called as the homunculus. I will show you a picture of the homunculus sometime later on.

So, this is the motor homunculus. So, leg, hand, trunk, torso, face, lips, thumb, fingers everything is represented over here. So, surgically if I were to you know put an electrode over here and then stimulate, then I would notice; which we do during surgery to for say for example, there is a tumor over here and I need to remove the tumor over here I need to know where exactly is the leg area; if you remember the operative photograph I showed in one of the earlier classes it is very difficult.

See here I am literally drawing lines and saying that this is there, that is there and everything is very defined, but most humans do not read textbooks and definitely not their brains. So, what happens is the anatomical structures which do not follow these rules rigidly. So, it is for that reason that you have to you know do stimulation to find out where some activity is.

So, I would start with somewhere over here, where the tumor is and then go anteriorly until I find that the leg has some moment. So, leg there are electrodes placed on the leg, muscles and when you put a signal over here you would find a muscle contraction being generated and that is how you say that this is your leg area.

Similarly, you put it over here you would find that the hand is moving. Somewhere on the facial area, some facial muscles would move. So, that is the idea of localization, utilization of localization and stimulation.

So, now we go to the remaining cell size so as to say. Now, anteriorly it is easy see. So, far I have described in very easy terms. So, you have a central sulcus which comes to the midline goes beyond the midline, you got one sulci anterior and one sulci posterior. So, that would define a motor cortex, pre motor cortex, one more gyrus anterior which may be broken incidentally will be the supplementary motor area supplementary it is supporting the supplementary motor area.

Now, anterior to the supplementary motor area you have to draw two sulci; one sulci goes like that and one sulci goes like that. Now what happens with that is, the frontal lobe. So, we now define frontal lobe.

Frontal lobe is the area anterior to the central sulcus. So, frontal lobe is divided into upper that is superior, middle and inferior gyri with two sulci superior frontal sulcus, inferior frontal sulcus. So, you know what was looking very complicated looks fairly simple, graspable, understandable and that is the purpose.

So, having said so, far the structure of these things, we can now find out some important things which are necessary. See most of us who are doing some research on imaging would like to find out where the motor cortex is and who want to see surgically where the motor cortex is interested in finding out the motor cortex of normal people, abnormal people. Abnormal in the sense say some patients with tumors or diseases where there can be a shift in the motor cortex.

So, how do you identify the motor cortex? So, first clue is the central sulcus which is behind the motor cortex comes up to the midline. The gyrus in front of the central sulcus which is fat when compared to the posterior one which is thin is the motor cortex the superior frontal gyrus forms a 7 over here, it continues with the motor cortex.

So, that is that is another landmark. So, there are multitudes of landmarks; the motor cortex as such goes to the midline beyond the midline to the interhemispheric fissure which is one of the few sulci which go across.

So, these are the techniques by which motor cortex is identified, I would be reiterating that in my imaging classes. Now, posteriorly what you would need to remember is only one set of sulci. So, like there is supplementary motor area, you draw an H over here. So, that is the H over here and then that is the H over here and then you make a H over here.

So, the H would ensure that you have got a superior and an inferior. So, the superior parietal lobule and the inferior parietal lobule. So, now we need to do some other stuff. So, we finish the frontal lobe and the parietal lobe; occipital lobe has not much features, there are some smaller gyri over here which are not I am not taking the trouble to name them and explain to you.

The parieto occipital sulcus so, that comes from the medial side from the midline to the surface and that comes over here. I will show that in a different section. Now, temporal mimics frontal. So, you draw one sulci here, one sulci here. So, that would be superior temporal sulcus, inferior temporal sulcus.

So, that is from superior temporal gyrus, middle temporal gyrus, inferior temporal gyrus. Now, the superior temporal gyrus is important because you have to curve it back and that forms something called as the angular gyrus. This part there is one area which is around the Sylvian fissure which is Wernicke's area.

So, these are the higher auditory associatory areas and that is the relevance of the two. So, doing the same thing on the opposite side, two sulci one and two and then you curve the one behind sorry the angle to form the angular gyrus. So, this forms the Wernicke and that is that completes that part of the story. So, in a very short span of time I have been able to demonstrate the basis of nomenclature of the various sulci, fissures of the surface of the brain and the relative importance.

Now, there are further landmarks say for example, I told you about the motor cortex.

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Similarly, the inferior frontal gyrus, you draw a V over here and then the central part of the V would form the Broca’s area so, left side. So, that is how it is divided and that is Broca’s area. So, we have Broca’s area, Wernicke’s area and the fibers go deep through there and that is the speech pathway. So, now that we have done this story what we need to do is we go to the midline and try to understand what is happening in the midline.

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So, wow it is a split, as the brain looking like that. So, what happens in the center is you have the temporal lobe, the Sylvian fissure is here. Sylvian fissure comes back over here and stops around here so, that has to be drawn. The temporal lobe forms a structure called as the uncus.

So, that is the uncus and that is just about there. Now, behind the uncus is the beginning of the brainstem. So, this is the same brainstem midbrain region which we have already discussed. So, behind the midbrain you have the colliculus, superior colliculus and the inferior colliculus, this is the brainstem, this is the uncus.

Now, if you recollect in the center of the brain, is the thalamus. So, what happens with the thalamus is if you have exactly cut in the midline, you would see the interthalamic adhesion or the thalamus per se and apart from the thalamus you would find the feature of corpus callosum.

So, corpus callosum is something which is here. So, you need to draw the corpus callosum and not only draw, it is the largest of fibers which go across the midline right. So, you would have the corpus callosum sitting here.

So, underneath the corpus callosum is the ventricle. So, underneath the corpus callosum is what? Ventricle. It would be the lateral ventricle. So, lateral ventricle on one side, this is if this is a cut in the midline you would notice that you cut through the interthalamic adhesions which I have described earlier.

Then the third ventricle would be here the connection between the third ventricle and the lateral ventricle would be here which is the foramen of mandrel of course, it is too compact to be shown in greater detail, you have to trust me on that. So, corpus callosum has various parts, this is a bend genome, body of the corpus callosum and the splenium of the corpus callosum. Splenium is related to the eye fibers thick, there are other parts not required.

So, the corpus callosum carries fibers from one brain to the other brain. So, you would imagine that it is a major important point of transfer of information across the hemispheres it is, but the relevance of the structure is not well known because we easily cut about anterior one thirds and patients do not suffer from anything major.

But if a substantial amount of corpus callosum then there is something called as disconnection syndrome in which there are funny kinds of manifestations of which happens when information which is to be taken over known to both hemispheres are not known.

Apparently, the patients do not suffer too much in real life because data is perceived bilaterally from both sides and there is a lot of mixing otherwise which happens, they do have problems and there are very interesting studies which indicate how functionally disconnection can result in loss of processing power.

On the center of the plane, there is only one sulcus which you need to know and which I have already drawn is the Cingulate sulcus. So, the cingulate sulcus, this is the motor cortex. So, cingulate sulcus is like this. So, it ends behind the central sulcus which I have drawn from the other direction, it goes behind and comes up to the superior surface and there is one more limb which goes anterior to the central sulcus.

So, the cingulate sulcus separates the cingulate gyrus from the rest of the sulci and gyri. So, these are important gyri and sulci. Now, we will go back to the occipital lobe. So, occipital lobe has the calcarine sulcus which on the banks of which is vision. So, calcarine sulcus then you have parieto occipital sulcus which I told you goes on to the other side and then you have lingual sulcus which is here. So, all of these form a triangle and a Y over here.

Now, on the temporal side of the story. So, temporal side of the story you have parieto occipital gyrus, collateral sulcus is a huge sulcus which goes from anterior to posterior and across this is reflected on the other side. See, remember there is a temporal horn of the lateral ventricle here; frontal horn in the frontal lobe, these are all parts of lateral ventricles.

So, lateral ventricle has components, and the collateral sulcus reaches up to that level. So, that in a nutshell is the anatomical intricacy of the of the lobes and it is a description of how to accurately identify, appreciate and understand what the methodology adopted is.

Now, these are broad terms if you see operatively from whatever experience I have had, it is in fact, very difficult to make out the central sulcus itself. So, central sulcus in the imaging it may be very obvious, but on table with the pia, with the arachnoid, with the veins, it is difficult. So, we do rely on electrical recordings to accurately identify the motor gyrus and the sensory gyrus.

There are electrical techniques of there is something called Phase Reversal in which the type of signal changes when you move from the sensory cortex to motor cortex. So, those are techniques which are used to delineate the motor cortex from the sensory cortex and that is one of the techniques of identification intra-operatively.

So, operatively when we have to find out where these areas are. Many tumors, they do not actually invade into this cortex and patients do not actually suffer from deficits before surgery. So, they do develop deficits, some patients do develop after surgery if there is some because they are closely placed, but displaced.

But how closely placed is always a problem and it is an unsolved problem; we do operatively take care, but there are issues with that. So, what I am actually trying to highlight is, say look at hand 5 fingers, named 5 fingers and some shape differences and that is about it you know it is just about the same for everybody. Face looks similar. There are so many differences between everybody’s faces, but yeah recognizable.

But if you look at the surface of the brain it is seriously difficult to pinpoint; there is too many variations which happen you know and as I told you even both sides. It is in fact, interesting why you know so much of diversity is allowed in cortical architecture in the brain what the point of study, but yeah, I do not have personally a methodology of how to go about it.

Now, going back into evolution many of this there is a lot of difference from between lower organisms and higher organisms in terms of their cerebral architecture. So, lower organisms do not have this much of a frontal lobe; higher organisms especially from the Chimpanzees or orangutans and humans have larger frontal lobes; and humans proportionately have very large proportionately have the largest frontal cortexes.

So, where the judgment thought decisions are being made, but even in lower organisms you can identify the motor cortex, we can identify sensory cortex. There are areas which are for olfaction and then there is areas for vision; obviously, language would not be there.

One area which I am not shown here is insula. So, insula is deep to the frontal lobe and temporal lobe, you have to actually split up on the Sylvian fissure. So, sylvian fissure has to be split and then you would see the insula the deep surface it is better shown on something else.

Insula has its relevance for surgically it is important to because tumors in that area difficult to operate. So, neurologically it is important because insulas can form as the focus of a seizure onset and regions which in the insula can inside seizure onset that is the relevance insular cortex also has similar sulcus architecture as the surface and there is a central sulcus here on top; there is a central sulcus in the insula; there are smaller sulci in either side of the central sulcus of the insula.

So, insular central sulcus incidentally is parallel to the largest central sulcus. So, that sort of summarizes and I hope I made some relevant thoughts on the topic. I think the surface anatomy is better done like this rather than draw on a piece of paper or on a brain. Because it is 3D and I feel 3D has to be thought in 3D not as 2D, you do not reduce dimensions in teaching. So, dimensionality reduction is not an option for teaching you can escalate dimensions which I think I have done.

And the objective being that whoever is listening has to have a clear understanding and more than the point of understanding is that once you understand some stuff it is easier to you know read it up from somewhere and proceed further from that, the difference between seeing and understanding or something like that I think I have highlighted earlier.

So, I think I will close down for today. And we will see what next has to be taught.

Thank you.