Advanced Neural Science for Engineers

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National Institute of Mental Health and Neurosciences (NIMHANS)
Lecture 39
Epileptic Seizure Detection and Classification

Hello everyone, welcome to this lecture. This lecture we will focus on the application of these equation of EEG. Now, until now, what we were learning is the biopotentials, whether ECG or EMG or EOG or EEG or even GSR, which is Galvanic Skin Resistance, but in that we have taken EEG as one of the biopotentials because we are interested in the brain signals. But once you understand how the EEG can be acquired, the next thing is how to apply that understanding to solve a particular problem.

Now, here we have addressed a very important problem which is epilepsy, epilepsy is also called as a seizure, and it is also known as fit. So, you may have seen someone in your lifetime, his body has a involuntary moment like he is involuntarily shaking and it is some in some cases, so much that the person cannot control and here if he falls down or she falls down and the only we do lot of unscientific treatment side by sometimes I have seen people taking the leather and giving it up or making the person smell that leather assuming that the fit will suppress.

But generally, this epilepsy can be detained by taking anti-epileptic drugs. And there is something called intractable epilepsy where the person has to go through the intraoperative surgery where the part of the tissue is resected. Now, which part of the tissue is resected, the part that is misfiring electrical signals. But before that, we need to first understand how the epilepsy or how the brain signals are obtained, and how they are analyzed by the electro neurophysiologist.

So, in that direction, let me tell you that the time taken to record the signal will be somewhere around 45 minutes. So, generally the patient is asked to be sleep deprived when the person goes into the sleep from that time, little bit before that to all the way to 45 minutes, the signals are continuously recording using the 10-20 manner where the electrodes are placed.

We have discussed and when the ways of putting the electrodes, number of electrode is 21. So, those electrodes will pick up the signals from different regions of the brain, whether it is

frontal or it is central or it is occipital or it is temporal or it is parietal so, all these different regions the signals are acquired.

And then based on these particular channels and the signal, the way the signal will behave the doctor can diagnose that whether the person has epilepsy or not one. Second is within epilepsy, what kind of different subcategories are there? So, there is something called absence seizure, there is something called focal seizure, there is something called generalize seizure, there is something called focal to generalize seizure and then there is normal.

So, not only that, the doctor has to identify it correctly, that means that no normal should be identified as epileptic, while in case of epilepsy also, if there is a better way to diagnose or sub-classified or classify the seizures, whether it is focal or generalized or focalize or absence, then it is very, very important, why?

Because based on that, the treatment is generally given, which drugs to get, how effective it will be, so, all these things are being are dependent on the way the signals are acquired and are diagnosed. So, the question is that if these things are known, there is a challenge, where is the gap, is not it? So, the gap is that like I said, a person needs to read an entire 45 minutes of data, is not it? It is cumbersome.

And there will be human errors, how to reduce those errors and how to help the clinician to go to that particular time in their 45 minutes timestamp. And if this algorithm can help the clinician by telling that okay first go to this timestamp between 10 to 15 minutes, or 10 and 11 minutes or 10 and 30 minutes just give an example.

In that you can see the sharp, you can see the spikes, you can see slow waves, and you can see mixture of two. That means that according to us, it looks like it is this kind of epilepsy led the clinician finally take a call. So, that tool will be a aiding a tool that can aid a clinician. So, can we design such tool that is the focus of today's lecture and you will see that we have designed it and in fact, there is a paper published by our group on understanding the signatures for the epilepsy seizure detection and classification.

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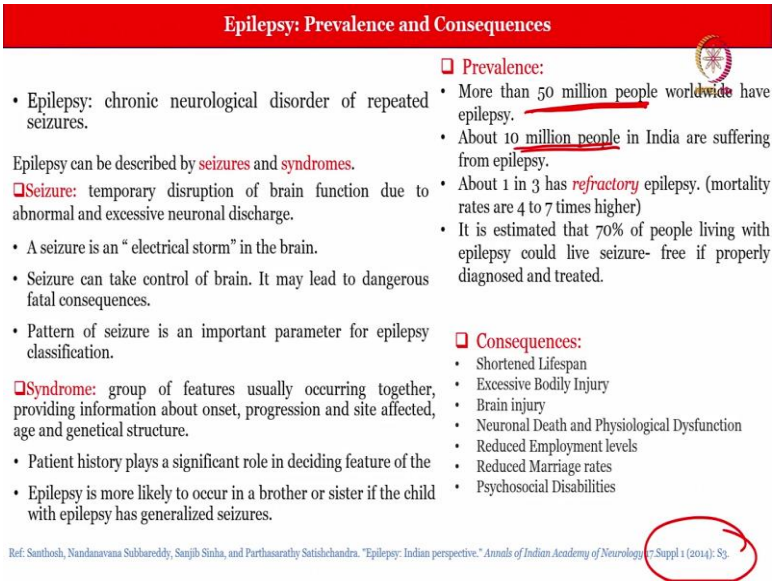

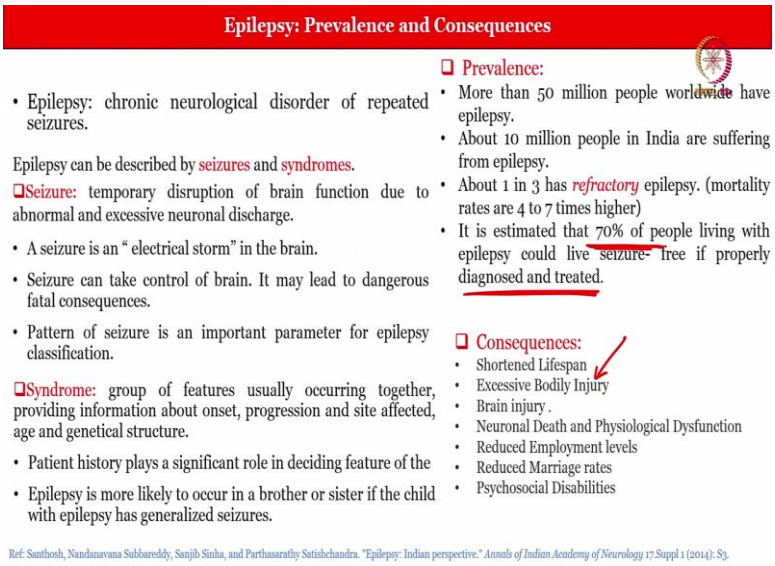

So, if you see the screen, the epilepsy, when we talk about epilepsy, let us talk about prevalence and consequences. First, Epilepsy is a chronic neurological disorder of repeated seizures. Epilepsy can be described by seizures and syndromes. What is seizure? Seizure is nothing but temporary disruption of brain function, you do abnormal and excessive neuronal discharges. So, this is because of the neuronal discharges. A seizure is nothing but like an electrical storm in the brain. So, it is really, if you do not take up that care of the seizure, it will really damage the part of the brain.

So, seizure can take control of the brain, it may lead to dangerous fatal consequences. So, patterns of seizure is an important parameter for epilepsy classification, how this is happening

and when it is happening and what kind of signatures are there, if you can somehow diagnose or can measure it will be useful.

While when you talk about syndrome because we are talking about epilepsy can be described by seizures and syndromes. So, what is syndrome? Syndrome is nothing but group of features usually occurring together, providing information about the onset, progression and sight affected, age and genetical structure, so all these things we can get it if you know this syndrome. Second is patient history plays a significant role in deciding feature of this particular thing, which is the syndrome or feature of the epilepsy. And then epilepsy is more likely to occur in a brother or sister if the child with epilepsy has generalized seizures.

Now, if we talk about prevalence, then more than 50 million people worldwide have epilepsy, you see more than 50 million people. About 10 million people in India are suffering from epilepsy at present now. And I think this is also already old data, if you actually it is a very old data, data is a very old data. So, this value would be way higher than 10 million. This was in 2014. I can find that out the latest data, but you can also find it out. My point here is that the number of people suffering from epilepsy is extremely high.

Next is about 1 in 3 has refractory epilepsy, that means the mortality rates are 4 to 7 times higher. So, they estimate that 70 percent of the people living with epilepsy could live seizure free, if properly diagnosed and treated, this very important thing, 70 percent of the people can be treated effectively.

Now, what are the consequences of this epilepsy, prevalence is that we know that okay, we are these are the numbers and if you can get some nice way to diagnose it early stage or right way of diagnosis or correctly diagnosing the epilepsy will reduce the number of fatal deaths that may occur due to the epilepsy. But what are the consequences of this particular disease? The consequences are one is shortened lifespan, it reduces the lifespan of a person. Secondly, excessive bodily injury because a person can suddenly fall where their person cannot control himself or herself.

Next one, there is a brain injury every time that episode occurs, there is an injury of the brain, neuronal death, like physiological dysfunctions, reduce employment levels, because a person who has many episodes of seizures difficult for the employer to hire the person because at any given time that that episode may occur, reduce marriage rates, and of course,

physiological, psychological disabilities. The point is psychological disabilities. The point is that the correct way of epilepsy diagnosis is very important.

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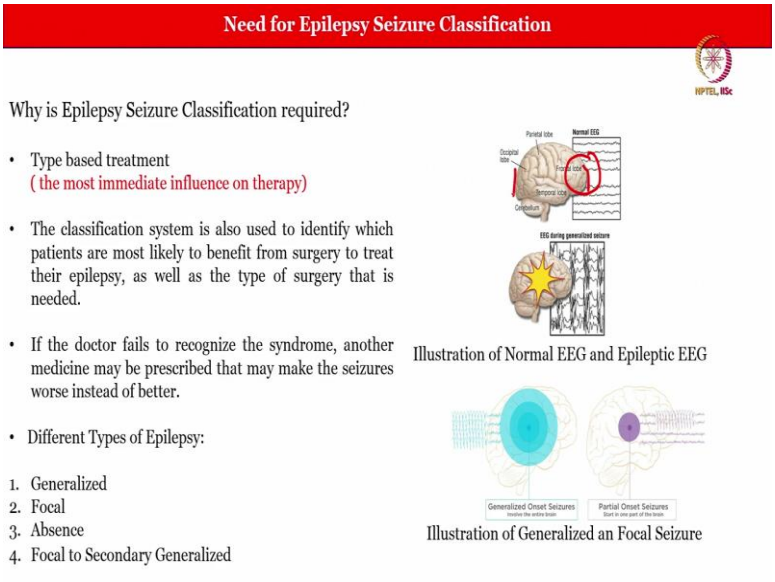

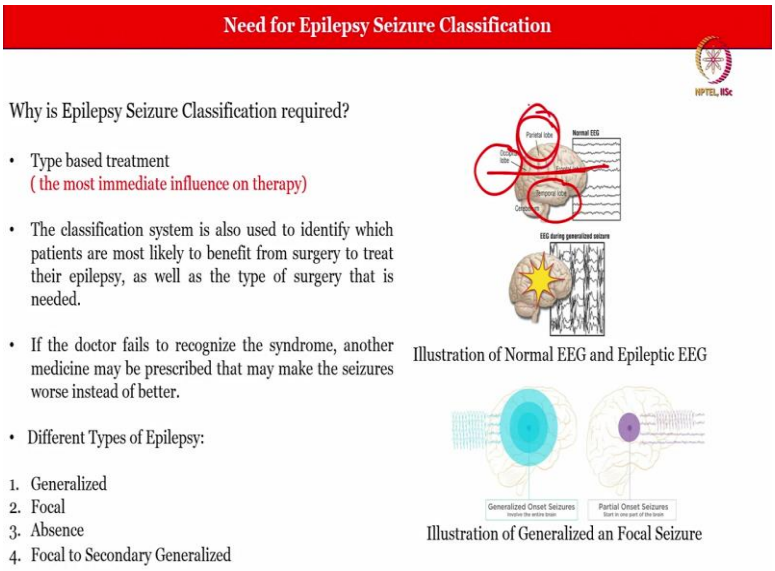

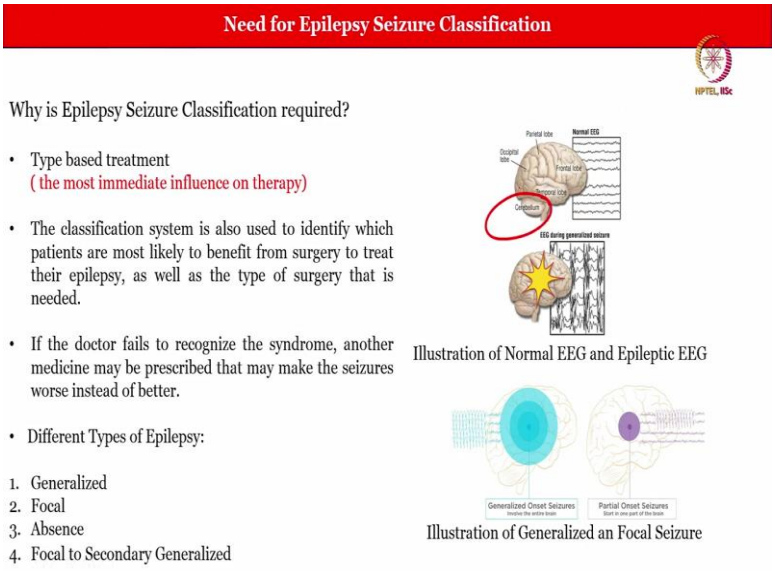

So, as I told you, the epilepsy if you can see, the frontal lobe is where your nose is, nose, the forehead and forehead below is this region, nazion, inion, if you remember, so frontal lobe, then you have temporal lobe, just about your ears, then you have parietal lobe, and then your occipital lobe, parietal lobe just at the back, if you draw a line like this exactly the back occipital lobe where you is used for visualization. And you have parietal lobe here, just before the occipital lobe and then you have a central region and of course, you have a cerebranium. So, this is the very simple way of showing the brain structure.

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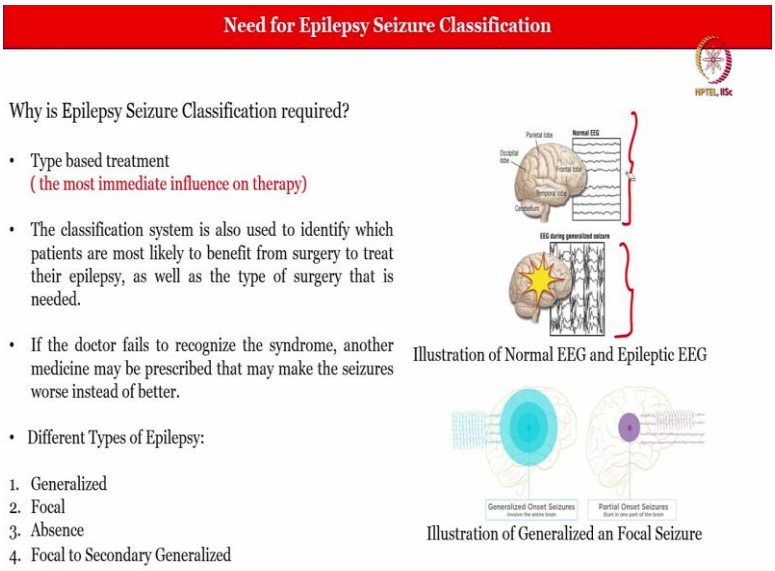

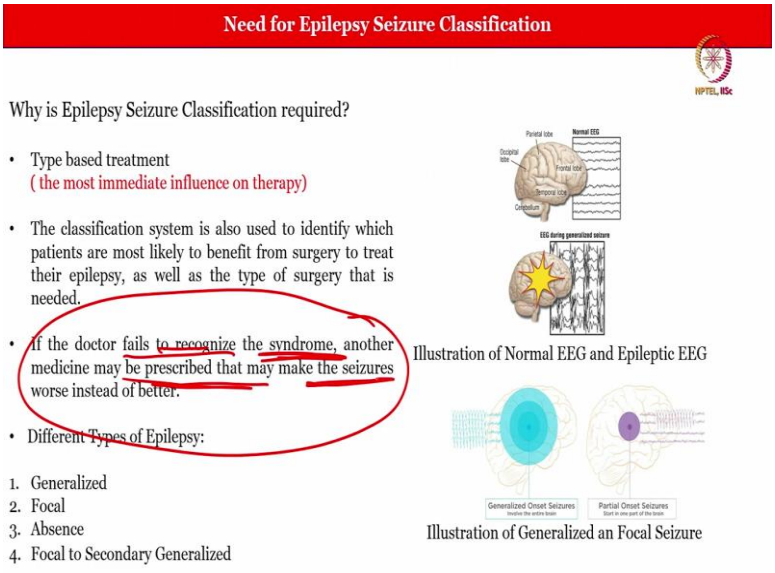

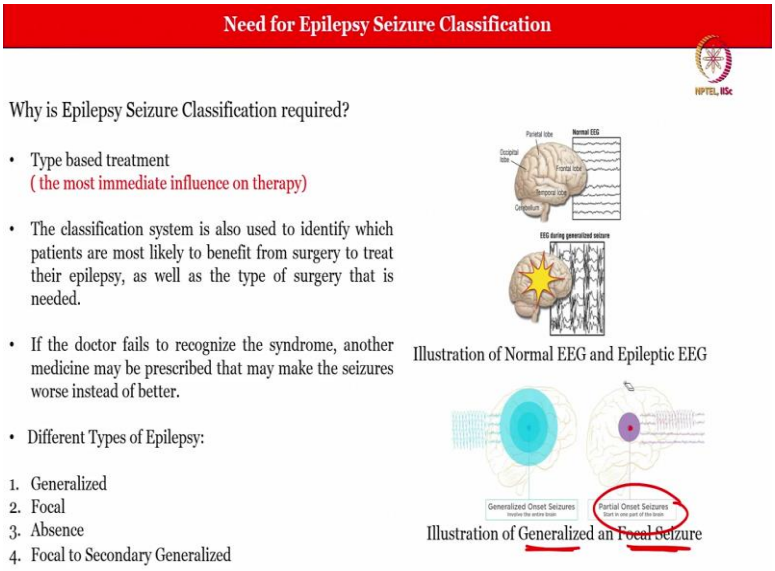

Now, when the normal EEG is that it looks like this, but when there is a generalized seizure, that means that it occurs anywhere in the frontal lobe, temporal lobe, parietal lobe, central occipital does not matter, anywhere it can occur, it is everywhere it is occurring, in fact, then you can see the signals like there, you see, it is like the haywire, it is everywhere.

So, this is the case when epilepsy or seizure occurs. And the importance of classification why it is important to classify epilepsy is because type-based treatment the most immediate influence on the therapy, what kind of medicines can be given, what kind of therapy can be given can be decided by a doctor, once a person knows that what kind of epilepsy is there.

Second is the classification system is also used to identify which patients are most likely to benefit from surgery to treat their epilepsy as well as type of surgery that is needed because like I said, in certain cases, there is something called intractable epilepsy where it cannot be

treated by taking the drugs and in that case, a person has to go for surgery and epileptic classification epilepsy classification would help to know that what kind of surgery is needed.

Next one is if the doctor fails to recognize the syndrome, another medicine may be prescribed that may make the seizures worse instead of better. So, that is extremely important. This point is extremely important if you just have read it, if the doctor fails to recognize the syndrome, and another medicine may be prescribed, that makes the seizure even worst, and that is why it is very important to correctly classify the epilepsy.

So, then if you want to classify epilepsy, you should know what kind of epilepsy is are there? So, the first one is generalized epilepsy then there is a focal epilepsy there is an absence and there is a focal to secondary generalized epilepsy, so, it is just an example of generalize on an focal seizure. So, these focal seizure partial onset of seizures started in one part of the brain and the generalized involve the entire brain everywhere the electrical signals will start misfiring and in the case of the focal seizure only a particular part of the brain starts this particular scissors.

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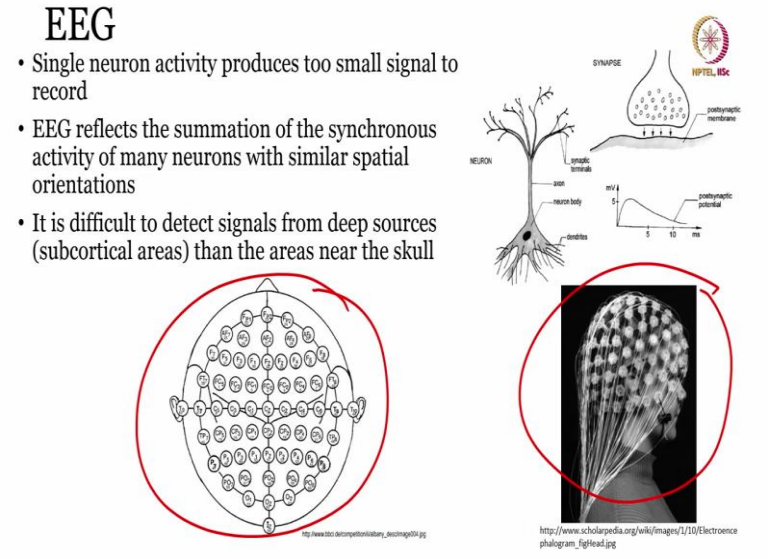

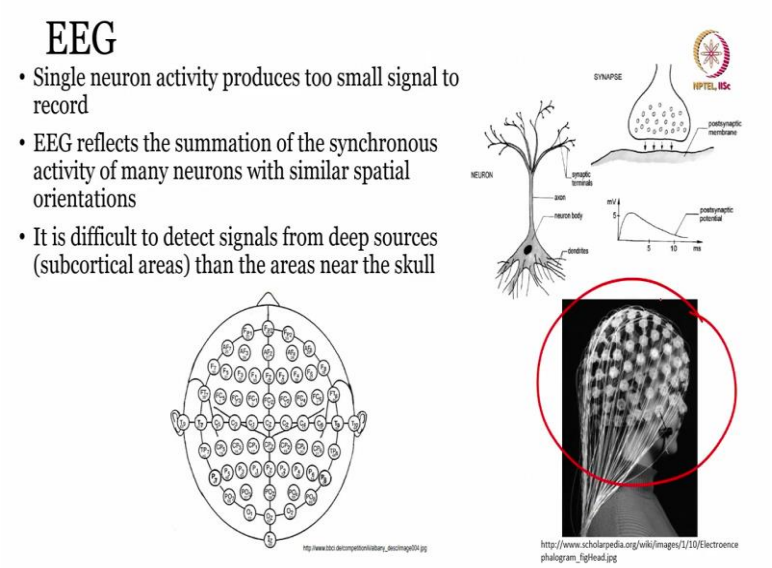

So, let us quickly understand recall if you remember about the EEG. EEG single neuron activity produces two small signal, EEG reflects the summation of the synchronous activity of many neurons because many neurons will bring together the EEG. We have learned this thing in our previous modules, it is difficult to detect signals from deep sources subcortical areas then the areas near the skull, and then we have seen that how the neurons while one single neuron will look like and then if you divide it or if you understand it, then there are dendrites and your own body axon and synaptic terminals.

And then we have seen this particular schematic where the 10-20 systems are placed on a person. And same way how the 10-20 system is defined is right over here. And you can see that all the even number of electrodes are on the right side, odd numbers of electrodes are on the left side. So, this is something that we need to remember now, why I have teaching you the same slide again because now the data that you obtained from this 10-20 system there are 21 electrodes is what we need to see.

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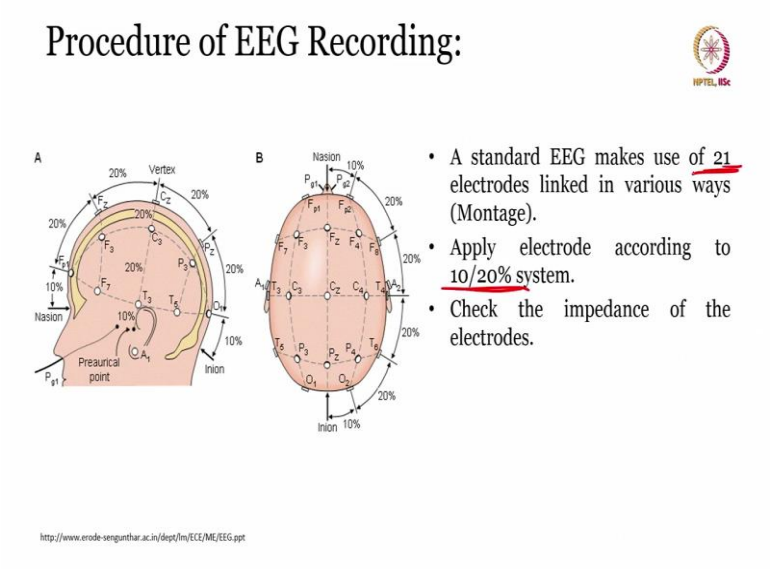

So, as you can see procedure this also will remember that how the systems are placed 10-20 percentage way in when given electrodes are there and we can use wet electrodes or dry electrodes.

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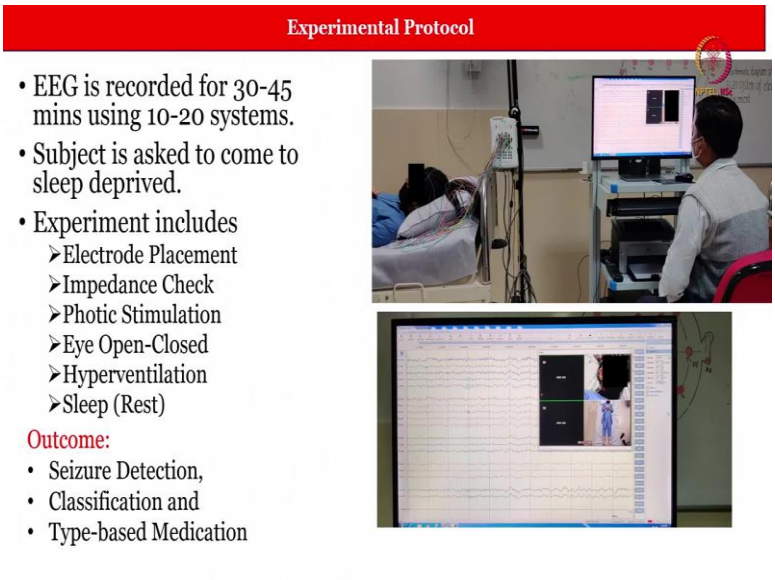

So, this is an actual photo of a person recording the data from a patient you can see all these electrodes are used to acquire the signal this is a signal that is acquired from these electrodes and this is another image that you can see all the signals from 21 electrodes are acquired. EEG is recorded for 30 to 45 minutes using 10-20 system.

Subject is asked to come sleep deprived and experiment involves now where to place electrodes, how to check the impedance because wet electrodes would have different impedance and dry electrodes to improve the impedance and reduce the impedance in fact, we use gel and that is why wet electrodes uses gel to reduce the impedance. Then you have photic simulation, you have eye open-closed, you have hyperventilation and you have sleep when you are resting. So, the outcome would be seizure detection classification and type-based medications.

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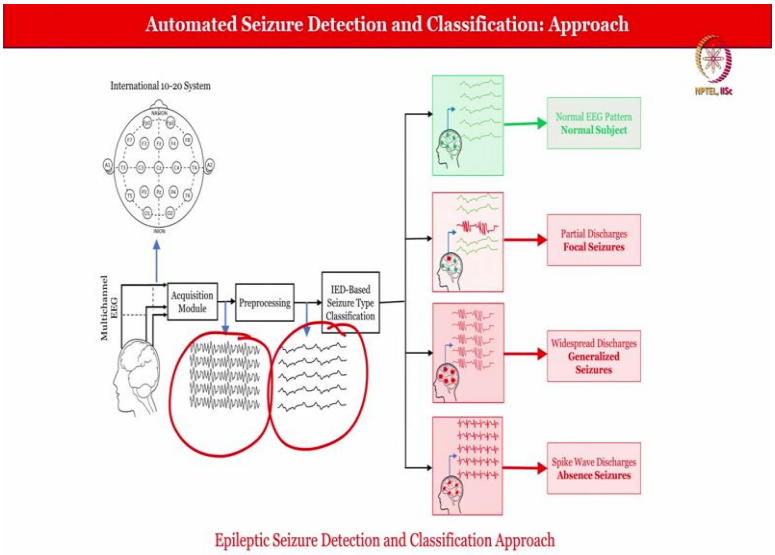

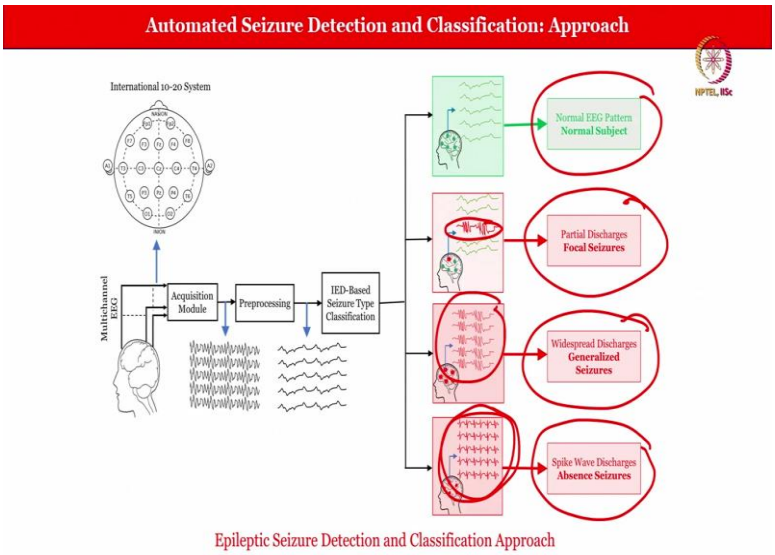

So, what you see now, in internationally 10-20 system is the recognize so, we place the electrodes and we then take these electrodes from the signals from different regions. When you have that then multi-channel EEG, you can have acquisition module preprocessing and

then IED based seizure type detection classification. So, this is before it then once we process it post process data.

Now, depending on that you can either say this subject is normal or there is a focal seizure only in certain region or is a generalized seizure all the regions or spike wave discharges and absence seizure, like views you can see like so, the waves are there. So, this spike waves. Now, we know then if it is just one particular region it is a focal it is everywhere it is generalized the spike waves and absences are. So, what to do with this.

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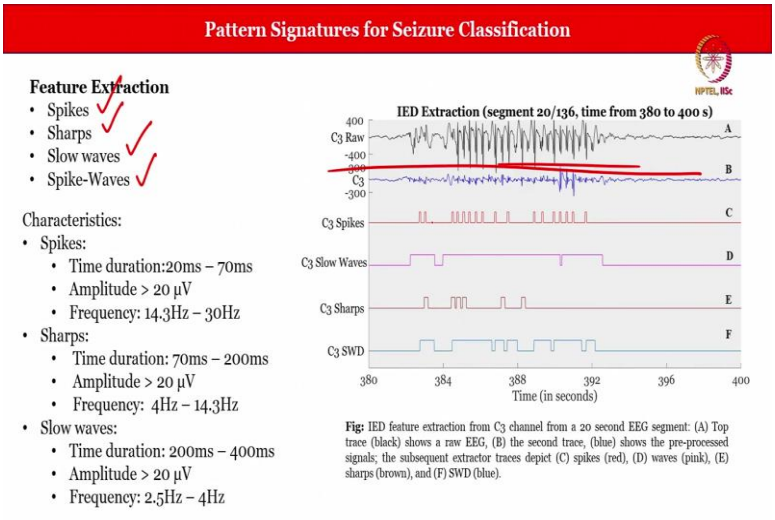

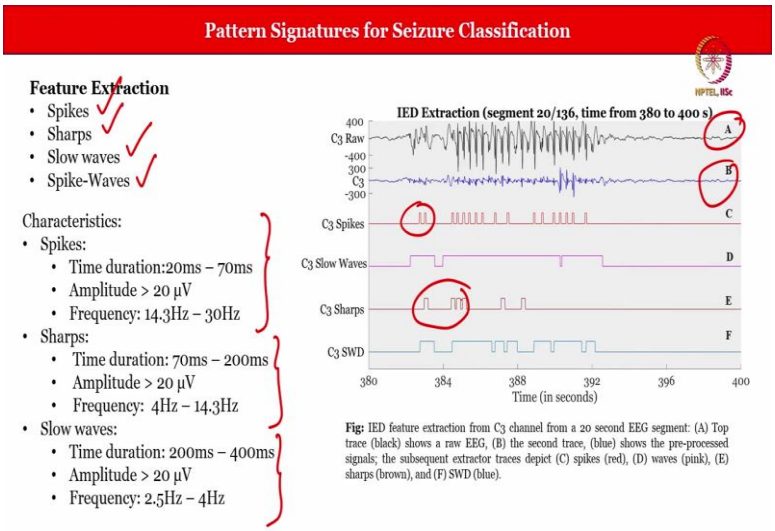

Pattern Signatures for Seizure Classification

Feature Extraction

- Spikes
- Sharps
- Slow waves
- Spike-Waves

Characteristics:

- Spikes:
  - Time duration:20ms – 70ms
  - Amplitude > 20 μV
  - Frequency: 14.3Hz – 30Hz
- Sharps:
  - Time duration: 70ms – 200ms
  - Amplitude > 20 μV
  - Frequency: 4Hz – 14.3Hz
- Slow waves:
  - Time duration: 200ms – 400ms
  - Amplitude > 20 μV
  - Frequency: 2.5Hz – 4Hz

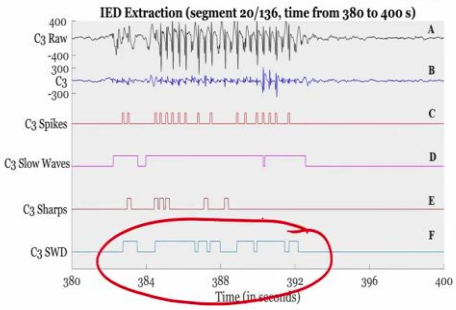

Fig: IED feature extraction from C_3 channel from a 20 second EEG segment: (A) Top trace (black) shows a raw EEG, (B) the second trace, (blue) shows the pre-processed signals; the subsequent extractor traces depict (C) spikes (red), (D) waves (pink), (E) sharps (brown), and (F) SWD (blue).

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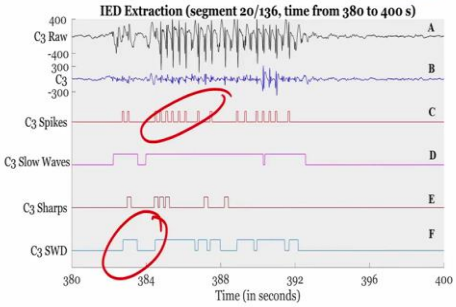

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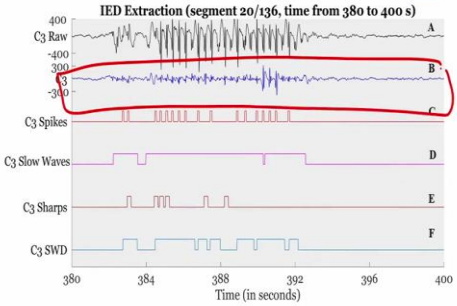

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Now, if you know that okay, these are the possible feature extraction parameters that means that we know that there are spikes, there are sharps, slow waves and spike waves this four feature extraction things are there, but how we will determine from the signal whether there is a spike or slow waves or there are as sharps. So, then the literature is what we have done the lab but the literature shows that these spikes can be defined when a time duration is between 20 millisecond and 70 millisecond where the amplitude is greater than 20 micro volts, the frequency is between 14.3 hertz to 30 hertz.

The sharps are defined when the time duration between 70 milliseconds and 200 milliseconds and the amplitude is greater than 20 micro volts where the frequency is between 4 hertz and 14.3 hertz while the slow waves are defined as the waves that are having time between 200 milliseconds and 400 milliseconds. You can see it is increasing, spikes 20 to 70, sharps 70-200, slowest 200 to 400 everything amplitude is greater than 20 microvolts and here the frequency is 2.5 hertz to 4 hertz.

So, frequency is in a way decreasing or is the different frequency range now 14.3 to 30 hertz, 4 hertz to 14.3 hertz, 2.5 to 4 hertz and here is an actual presentation of the EEG data extracted using the 10-20 system and you have just taken data from one particular group which is your C 3 channel numbers C 3 for about 20 seconds and you can see that the first one which is the A this one is nothing but the raw EEG signal.

Now second one this B one is your preprocessed signals and the subsequent spikes, depicts C is spike, spike 70 milliseconds, rather than 20 microvolts, 14.3 to 30 hertz spikes, slow waves because it is between 200 and 400 milliseconds greater than 20 microvolts and 2.5 hertz to 4 hertz sharps because we have 70 milliseconds 20 and 70 milliseconds sorry 70 and 200 milliseconds you can see here, they are a little bit different than the spikes and then you have 4 hertz to 14.3 hertz is a frequency and then you also have something called slow wave discharges.

So, you have waves and it is discharged through the brain. So, this all is nothing but the electrical signal. Now, whether we put it in this form or you form in this form, actually whatever we are measuring it is through this particular signal which is B here. So, the preprocessing algorithm and the post preprocessing algorithm is very important.

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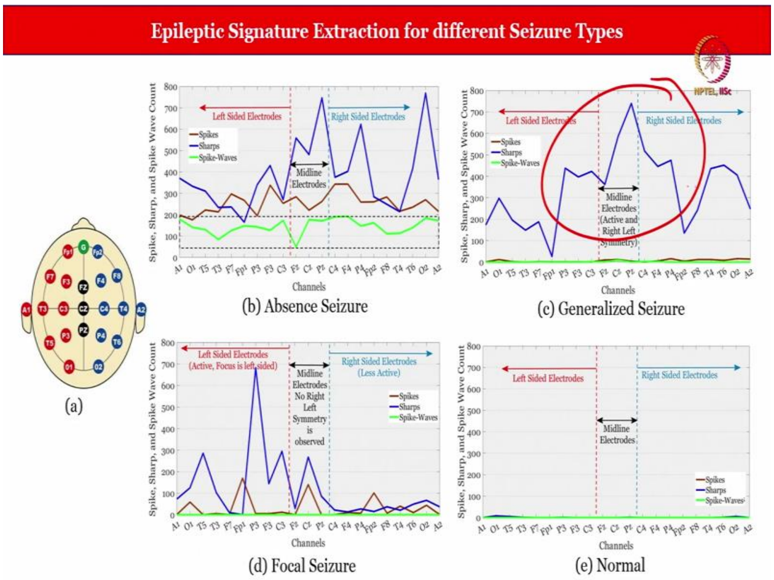

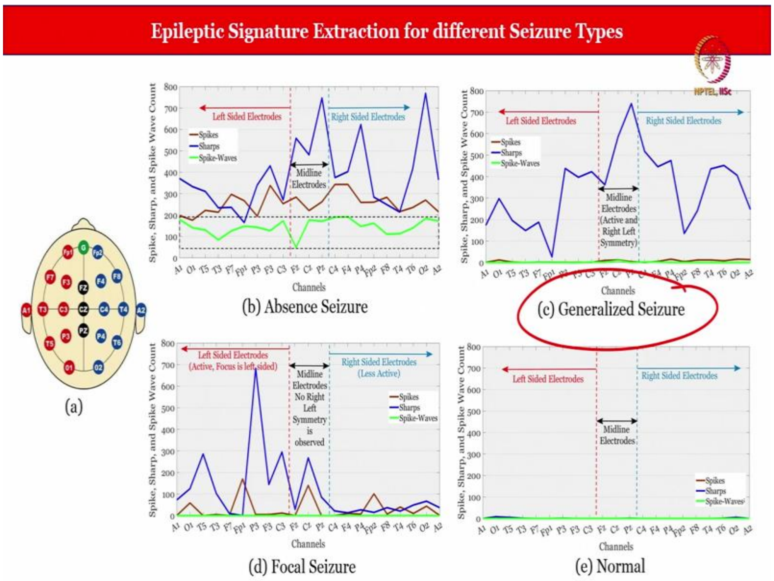

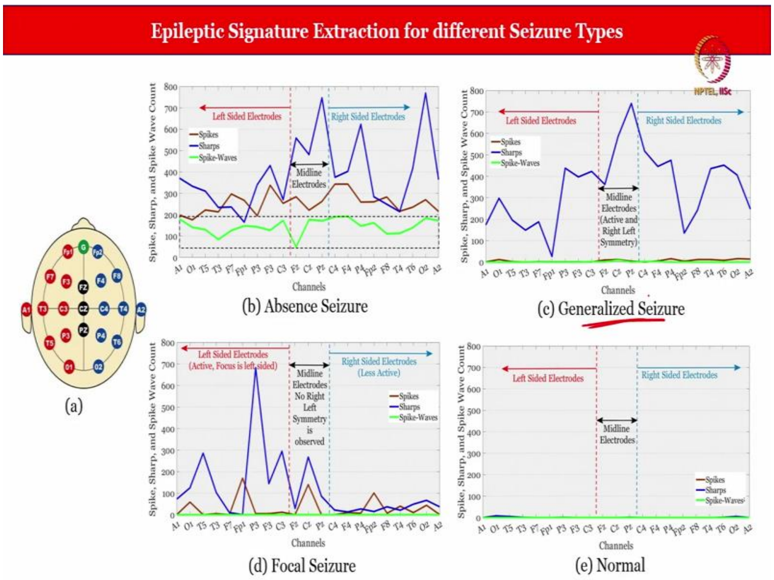

Now, when we did that for a lot of subjects about more than 80, what we found is that the if you put the channel number as x axis and these spikes charts and spike wave count and the y axis then now you know how we can calculate. So, then we found that the sharps on the right side of the or right channels and the left channels along with the spikes and spike waves, can be very distinctly seen, you can see very distinctly it can be seen of course, as the sharps are little bit larger, the counts are more but so, is the spikes and spike waves.

But in case of generalized seizure, we were not able to see any spike waves or spikes only sharps were observed and also uniform you can see on the right side, left side kind of uniform. So, this is what we call as a generalized seizure when the spike waves and the spikes are not observed, but when we observe all three things spikes, sharps and spike waves, we call it as a absences.

Now, another thing that we observed is that if it is focal seizure is that then only sharps and spike waves would not be there but sharps and spikes would be there and that too also predominantly on the left side or the right side is to not be uniformly distributed like in the case of generalized seizure. So, based on that and based on number of counts, we can say that it is a focal seizure.

Finally, for the normal subject, we were not able to identify any kind of the feature extractions either it is a spike or sharps or spike waves, nothing was significant in case of the normal subjects. So, now, if we know that it is normal subject versus a subject suffering from epilepsy, then using the tendency system we can differentiate whether a subject is suffering from a generalized seizure, absence seizure or subject is normal.

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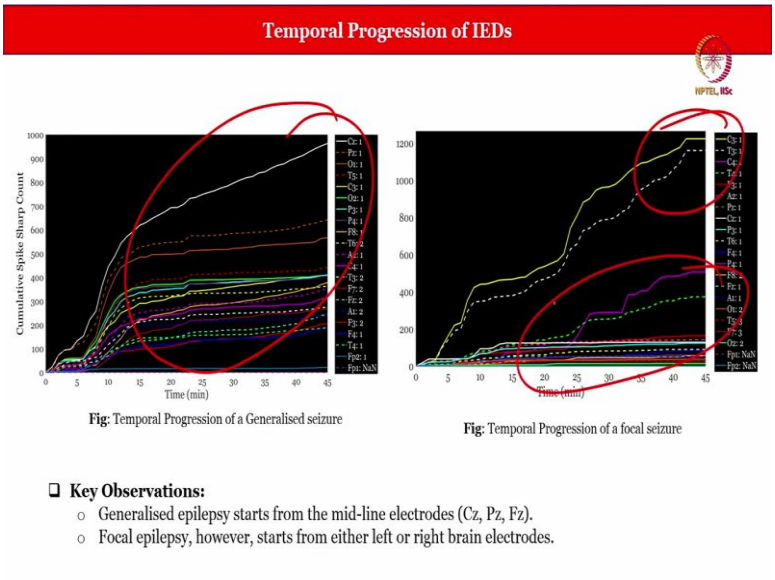

So, in this extremely beautiful plot, where you can see that a for generalized epilepsy all the electrodes are kind of increasing the number of counts. So, cumulative spike counts, spike and sharp counts are increasing uniformly, but in case of the focal seizure only a few electrodes, subsequently increases, all the electrodes are more or less uniform. So, the key observation, starts from the midline electrodes, C z, F z and P z. While the focal epilepsy how it starts from either left or right side of both electrodes.

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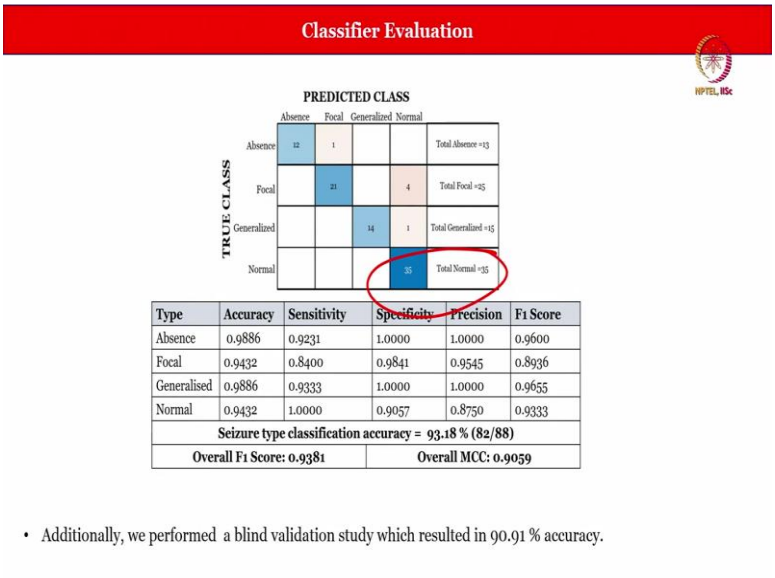
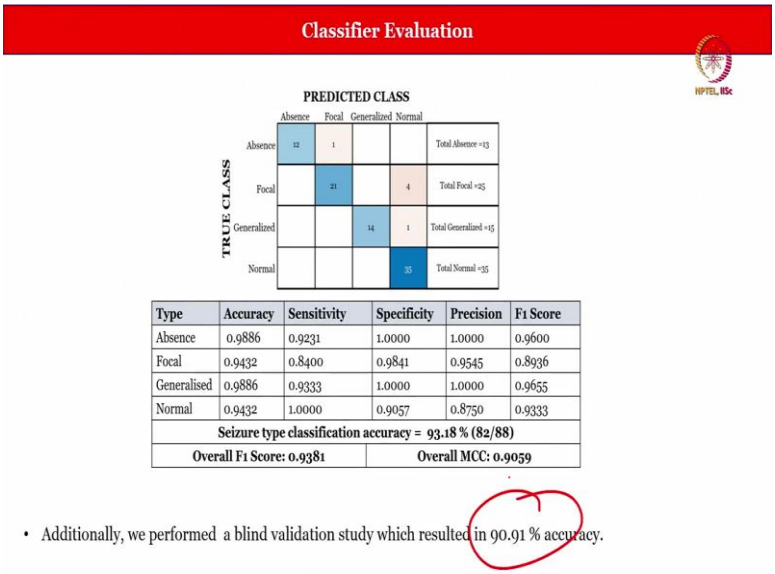


Type	Accuracy	Sensitivity	Specificity	Precision	F1 Score
Absence	0.9886	0.9231	1.0000	1.0000	0.9600
Focal	0.9432	0.8400	0.9841	0.9545	0.8936
Generalised	0.9886	0.9333	1.0000	1.0000	0.9655
Normal	0.9432	1.0000	0.9057	0.8750	0.9333
Seizure type classification accuracy = 93.18 % (82/88)					
Overall F1 Score: 0.9381			Overall MCC: 0.9059		



So, now like I said, we have done extensive analysis from lots of subjects. And what we found is that the seizure type classification of algorithm was close to 93.18 percent. That means 82 out of 88 were correctly identified. Let me also tell you that all normal well identify as normal only, that is a good thing. Only for generalized we missed one and for focal, we missed 4 and for absence, we missed 1. So, that is the performance of the algorithm. We are working on improving it.

The overall F 1 score was 0.9381 And MCC was 9.9059. We also run blind reduction, which resulted in 90.91 accuracy, where we were not knowing that what kind of subject is there an algorithm predicted that this subject suffers from so and so seizure or the seizure can it is absence or focal or generalize or not.

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As I was telling you that we have published this paper in biomedical signal processing and control, and these are nothing but spatial temporal analysis of interracial EEG for automated detection and classification. And you can also we have filed a patent because I will tell you the reason of this pattern, because now we can use the algorithm and can aid the clinician to quickly get the diagnosis done. Of course, this was in press release and all these things, but the point is that if you have this kind of seizure classification algorithm, and you know that how to how to measure those EEG data, then you can very easily help a clinician or aid declination to come up to far faster diagnosis or also to save the time.

Now, one thing that I have not told in these particular slides is that not only the algorithm was able to classify the seizures or seizure type, but also was able to tell the clinician which time to go, so not only saving the time, but also helping which kind of seizure is that so, both things in one go. Of course, the data is not that great, because the performance is not great, because it is 90.91 when we are looking at the blind study to really be very high, we are we are optimizing the algorithm. But my simple point is, knowing the EEG, understanding the EEG, you can help to fill a very important gap in the area of epilepsy detection.

So, with that, we will stop this lecture here. We will continue with the epilepsy and the how to understand the anti-epileptic drugs and its efficacy by using micro electrode array. We will see in the next class, we will see how the fabrication of this micro electrode array is done and how we can acquire the signal. Till then you take care. If you have any questions, feel free to reach us through the NPTEL forum. I will see you next class. Till then. Bye for now.