Utilization of the ICS Impulse for Oculomotor Assessment in Videonystagmography

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- [Mary] Thank you very much, Anna and hello everyone, on behalf of Natus Medical Incorporated welcome to today's eSeminar entitled Utilization of the ICS Impulse for Oculomotor Assessment in Videonystagmography. I'm Mary Ormson, Medical Education and Training Manager for Hearing and Balance at Natus, and I will be moderating today's event. I'm very pleased to introduce our speakers Dr. Alida Naudé and Kayla Van Rie. Dr. Naudé is a diagnostic research and training audiologist working at Amtronix Diagnostics and the University of Pretoria South Africa. She received her Doctorate in Audiology from the University of Pretoria in 2015. At the end of 2016 she completed her Post Doctorate Fellowship at the Center for Augmentative and Alternative Communication. Special areas of expertise and research include Ethics and Personal Development, Evoked Potentials, Vestibular Audiology and Phototoxicity. Dr. Naudé has authored more than 10 articles in accredited journals and has also served as the editor of the special journal edition about Ethics in conjunction with international researchers. Alida has co-authored a research methodology book as well as a book chapter related to newborn hearing screening. Kayla Van Rie is a clinical and training audiologist at Amtronix Diagnostics with experience in medical, corporate, educational, and academic settings. She obtained her degree in speech therapy and audiology from the University of Wits, South Africa. Kayla has a special interest in the vestibular audiology and manages the Vestibular Clinic at the University of Wits as part of her student training. She consults on advanced cases and provides regular training workshops to encourage colleagues in their journey of continued professional development. I will know turn the presentation over to Dr. Naude and Kayla.

- [Alida] Thank you Miriam for the introduction, and thank you Natus for the invitation to present on this topic on audiology online. Good morning, or good afternoon depending from where in the world you are joining us today. I am Alida and it's a great privilege for me and my colleague Kayla, who will be sharing with you later in this presentation, to share with you on oculomotor assessment in the balance clinic. Specifically, we want to talk about the traditional VNG test battery and how it compares with the ICS impulse

test. We use both systems in the clinical setting and we also provide student training at one of the Universities in South Africa, and regularly consult in hospitals and private balance clinics. So during this presentation, I just want to click over to the next slide, we will describe the use of the ICS Impulse, you can see the system on the left of your screen, for the assessment of the oculomotor pathway in patients with vestibular pathology. Specific attention will be given regarding which test analyzes some of the neurological pathways related to the ICS chart of VNG that you can see, on the right of the screen. The use of a different protocol using the ICS impulse goggles compared to using the traditional VNG protocol will be explored. As you can see, you can do gaze, positional, positioning, and caloric testing on both systems although that is not the focus for today.

So before we start the presentation, let's just quickly go through the learning objectives. At the end of this presentation, you should be able to describe the clinical relevance of the different assessments within the ICS Impulse System specifically related to oculomotor function. You should also be able to visualize the vestibular and neurological pathways associated with these. And lastly you should be able to identify which VNG and ICS impulse assessments are similar in terms of neurological pathways. Okay, so lets start off with a more traditional approach. We know that VNG is a standard in balance assessment. So what is VNG? VNG stands for videonystagmography. It is a test that directly measures eye movement by tracking the pupil using infrared video technology to record a patients eye moments including a type of involuntary eye movement called nystagmus. It, I'm referring to the nystagmus, happens when the brain gets conflicting messages from your eyes and the balance system in the inner ear and can cause dizziness. Now you can briefly get nystagmus when you move your head in a certain way or look at some type of patterns but if you get it when you don't move your head or if it last a very long time, it may mean that you have a disorder of the vestibular system. As mentioned on the previous slide, the VNG test battery consists of oculomotor, positional, positioning and caloric tests. It is used

to find out if the disorder is related to on the one hand, the vestibular system, in other words, the balance structures in the inner ear like we refer to as peripheral, or on the other hand central which means in the part of the brain that controls balance. It is important to remember that VNG results do not differentiate between a labyrinthine lesion and an eighth nerve lesion as both are peripheral. The oculomotor evaluation, as already mentioned, is our focus today, provides a global assessment of the neurological pathways associated with oculomotor function.

So at this point we have to ask what is the oculomotor system? The oculomotor system is the part of the central nervous system which functions mainly maintaining visual stability and controlling eye movement. We often refer to the function here as gaze stability. It is a very delicate system. Now the fovea, which has the visual acuity on the retina, can only discern an area with a size of about 2.5 centimeter, held at arm length. So to gain precise and clear vision, the eyes must be directed precisely at an object of interest and held in a stable state. In other words, the eyes lock on to the target. Something goes wrong in the oculomotor pathway, the patient will experience blurred vision or diplopia, which is double vision if the eyes do not properly align with each other. If you haven't done this yet, I really want to encourage you to look at YouTube videos showing double vision from the patient's perspective. This is really very helpful in understanding how this affects our patient's quality of life. Okay, so the oculomotor system consists of interconnected regions throughout the central nervous system that interacts to control various eye movements. It includes different brainstem nuclei, the superior colliculus of the midbrain and various regions throughout the cerebral cortex. And we will look at these areas more closely throughout the presentation. But five distinct eye movement systems are responsible for voluntary and reflex of a visual target, namely vestibular, optokinetic, smooth pursuit, saccadic and vergence. For oculomotor assessment using the VNG system, we will discuss saccades, smooth pursuit or tracking, and optokinetic as you can see on the slide. We will then discuss the role of VVOR and VORS which is available in the ICS Impulse

System, as you can see on the right. We will shortly review the neurological pathway of each test, discuss how they are performed, and look at how the results are presented. But before we continue with more detail, let's quickly review how oculomotor assessment will help us with our differential diagnosis.

Now the most common abnormality that you will see during your assessment is spontaneous nystagmus. This will give valuable information regarding possible site of lesion and naturality. Pathologies that could impact on oculomotor function include for example MS, neuropathy and diabetes, aneurysm or stroke, tumor, medication and many others which I'm sure you're familiar with if you work in this field, that have been documented in the literature in detail. But remember that oculomotor test results can be influenced by factors such as anti-vertigo or anti-nausea drugs, anti-convulsants and nicotine. It can also be influenced by lack of alertness and attention, for example under the influence of tranquilizers, alcohol, street drugs or even just with fatigue. That's important for giving instructions to our patients before the test, but also taking a fair case history. Okay, so here you can see that both systems start with calibration, and it is done by using the center of the pupil.

Calibration is very important as it calculates a conversion factor between measured parameters and eye movements. The calibration is inaccurate, the results will be inaccurate as well. Now according to ASHA, base practice either tracking or saccades can be used. The ICS VNG system uses tracking as can be seen on the left, while the ICS impulse test on the right uses saccades. Both systems will tell you if the calibration is accepted and within the expected range. A default calibration is available on both systems, although I would not recommend using this feature unless there's absolutely no other way of testing, as it can really impact on the accuracy of your results. Okay, so let's start with saccades. Both systems include saccades as a test option. The saccade is the French word for jerk. So the eye execute a series of very rapid movements from one point to another, stopping briefly at each point which we call at

the fixation point, to check the visual image. The neural command generating voluntary saccade appear to reach mainly in a region of the frontal lobe referred to as the frontal eye field. Now if you look at the picture, you will see the frontal eye field towards the top left round about at your 10 o'clock.

Next to it you will see the supplementary eye fields which provides input to the frontal eye field. Further to the right you will see the parietal cortex which also provides additional input to the frontal eye fields. But the parietal cortex also receive information from the frontal eye field and plays a central role in focusing attention on visual input and interacting with sensory processing areas of the brain. Now if you follow the arrows, you will see that the projections from the eye field terminate in a beautiful teal color shape. This is the superior colliculus. If you look at the right bottom, it is marked there. If you follow the arrows going from the superior colliculus it ends in two brown egg-like structures. One is the midbrain's vertical gaze center and the other is pons horizontal gaze center. These structures in turn send messages to the neurons controlling eye muscles and to produce conjugate eye movements, which means eye movements that are symmetrical.

These neurons are also referred to as PPRF or paramedian pontine reticular formation, which plays an important role in all ocular motor activity and will be mentioned again. So if we look at the test procedure, so during saccade we're going to examine the patient's ability to make fast and accurate eye movements. We are going to record the eye movements as the patient looks back and forth between the targets in the horizontal plane. If we're using the chart of VNG, the stimulus is generated on the light bar. And if using the ICS impulse, it is generated with the laser beam from the goggle and projected on the wall. The target with move with randomized amplitudes and direction. It is recommended to run the test for at least one to 90 minutes to collect enough data. It is important to instruct the patient not to move their head and not to anticipate target movements but to only move the eye once the new target is visible.

You also have to look at the patient because sometimes they don't even notice that they are moving their head or they just forget because they're focused on the stimulus. Sometimes you have to also stop and reinstruct. Now we want to look for the patient's best performance.

So if you see an abnormal result, it is really valuable to reinstruct and repeat the test. The true abnormality is consistent and repeatable. So here on the next slide we have displayed an example of what the test results will look like. We will see that there's hardly any difference between the two systems. Normative data for latency is based on age, related norms, but all other norms are the same regardless of age or gender. Now for both systems, results are displayed for amplitude, which measured in degrees, which is the size of the jump between the initial position and first stop of the eye movement. Then peak velocity, which is displayed in degrees per second. This is the speed of the eye movement. Accuracy shown in percentage, which can be described as the size of the excursion compared with target excursion and then latency in milliseconds, which is the reaction time or time between target movement and first eye movement. So just to refresh your memory and also in conclusion before we move to tracking, I will mention the most common abnormalities documented for saccades which is saccadic slowing and delayed saccades. Now abnormalities in the saccadic system denote a central lesion with the most common etiologies including olivopontocerebellar atrophy, Huntington's disease, progressive supranuclear palsy and Parkinson's disease.

As mentioned previously, we need to rule out drugs, so remember things like caffeine, codeine, marijuana. We also need to think about drowsiness and inattention before attributing abnormalities to central causes. And remember at any point, you can repeat to make sure that it is a reliable result. Okay, so let's move on to tracking. The tracking module is specific to the chart of VNG system protocol and not available in the Impulse System software. Tracking also called smooth pursuit, refers to tracing eye movements

that enable stable gaze to be sustained on a moving object or on a stationary target when the head is moving slowly. As with saccades, smooth pursuit movements are also mediated by the neurons in the PPRF but are under the influence of motor control centers other than the superior colliculus and frontal eye field. So the motor processing pathway consists of the middle temporal area that you can see circled in the green at the bottom, and the medial superior temporal area circled in maroon just above it that together determine the speed and direction of image motion. Now the SEF, remember that's the supplementary eye field, also takes a more active role in planning of smooth pursuit and is involved in prediction and anticipation of future target motion as well.

Smooth pursuit activity has also been found in the parietal and occipital cortex. The cortical areas project to the pontine nuclei which project to the flocculus complex and vermis of the cerebellum, which projects to oculomotor neurons. The tracking system is considered the main contributor to fixation suppression. Now this is very important when we talk about the test in the ICS impulse battery, so remember this, which Kayla will present to you later on in this presentation. Okay, test procedure again. So with tracking, we want to evaluate the visual smooth pursuit system by examining the patient's ability to generate slow foveal tracking eye movements. We are again going to record eye movements as the patient follows a visual target moving smoothly back and forth in the horizontal plane. Now the stimulus is generated on a light bar using sinusoidal waveforms with a peak-to-peak amplitude of 30 degrees at frequencies of between 0.2 to 0.7 hertz. So we'll usually start slow, go faster, slow down again depending on how many cycles you are doing. It is good to run two full cycles unless the first cycle is really very clean. But if you're not that experienced, it's always better to get more information. Again, ask the patient to avoid head movement. Sometimes you actually have to hold their head still because some people find it extremely difficult to keep their head still. As with saccades, again we're looking for the patient's best performance. If we have to reinstruct, we'll redo it. It is good because it's important for us to get reliable information. So here I'll show you the analysis screen. This is an

example of tracking test results are displayed in the system. Abnormal tracking, also called defective pursuit usually means that the patient cannot follow a moving target and instead approximates target motion using successive saccades which denotes a central site of lesion.

Now we're gonna move on to optokinetics. Now the optokinetic module is specific to the chart of VNG system protocol. Although it's not a named protocol on the ICS Impulse Systems, it is possible to manually provide the stimulus and record the eye movement for interpretation. We have to, however, consider that when optokinetics are tested with a light bar, as is the case with the chart of VNG system, it is more a test of the tracking system. Now the optokinetic stimulation originates from the retina and requires full motion of the full visual field. In contrast, the tracking stimulus must be small enough to fit on the fovea, which makes testing with a light bar ideal for resisting tracking but not optokinetic responses. So although the tracking in optokinetic mechanisms both originate from the visual system, there are distinct differences between the two and how they should be recorded.

Now optokinetic eye movements are reflexive, whereas tracking eye movements are voluntary. Now optokinetic response supports the VOR or vestibular ocular reflex, in maintaining stable gaze. So again, gaze stability during constant velocity or low acceleration head movements by producing eye movements in the direction of visual motion. A good example to explain optokinetic stimulation is when you're in a car and staring out the window while someone else is driving. Stimulation of the optokinetic system generates a strong sense of self motion, which is not a feature of the tracking system stimulation. So optokinetic nystagmus is normal in people without vestibular pathology. If someone recorded your eye movements while you're staring out the car window, you will be able to observe your own nystagmus. An abnormal optokinetic response can now even be recorded if there's abnormality in the anatomical physiological optokinetic reflex pathway. We can therefore attempt to evaluate

optokinetic eye movement by presenting a full field visual stimulus via a big screen or projector and instruct the client to avoid fixating on any part of the visual image and literally just stare in front of them while the image is moving. And you should try this yourself sometime. If you're just looking at a optokinetic picture that is stimulating this, there's nothing you can do. You just stare in front of you and you try not to move your eyes. But because it's a reflex, it's nice because you can't have a malingerer in this test. If we are truly testing the optokinetic system, we are evaluating an oculomotor reflex and the neural pathway involves the cortex, the brainstem and the cerebellum.

Now the consensus of evidence is that optokinetic eye movement is mediated by the occipital lobe. What is interesting is that research suggests that the final neuronal layer for optokinetics correspond to that of the voluntary saccades and smooth pursuit respectively and the rise in the same brainstem neurons. Okay, so test procedure for the chart of VNG will record eye movements as the patient watches a series of visual images moving first to the right and then to the left in the horizontal plane on the light bar. On the ICS impulse, you will have to project the visual image on a screen. Now you can find images on YouTube. Usually it is black and white stripes that move to the one side and then to the other side. On the VNG, the stimulus is a constant velocity movement at 20 to 40 degrees per second. And then you just select the speed. It is recommended to record eye movement until you have at least five good nystagmus feeds for each direction. Some literature will recommend 20 seconds, but if you get five good nystagmus feeds in less than that, you can stop. It's quite difficult, so it's quite tiring for the patient.

Again you need to ask a patient to avoid head movement or you need to hold their head, and look for the patient's best performance as with the other oculomotor tests. Now here you can see an example of optokinetic test results in both systems. You will note that although the ICS Impulse System also determines the gradient of the nystagmus, I didn't include it in the slide 'cause this is to show you the test setup

picture. Now you will see that I've performed this test on the gaze, but I selected other as indicated by the blue arrow on the right bottom of the slide. And then I will know that other in gaze was my optokinetic test. When analyzing the results, you want to determine if the patient is performing equally in each direction. The nystagmus slow phase velocity should be greater than 75% of the target velocity for each direction. So just as a point of interest, we know that there are many conditions producing abnormal optokinetic responses. But in most of these conditions, the diagnosis can be made without optokinetic results. The literature even mentions five general conditions where optokinetic assessment is extremely valuable to assist with the diagnosis. Now the first is suspected poor visual acuity in children. Secondly, directional asymmetry secondary to deep parietal lesions. The third condition is suspected subclinical internuclear ophthalmoplegia, which is important for discussion later in this presentation as well. We will talk about that again. The fourth condition is suspected sylvian aqueduct syndrome. And lastly, third nerve misdirection syndrome. Now that concludes the end of my section, which focused more on the traditional test battery. I'm going to hand over to Kayla now where she will share more regarding the tests specific to the ICS impulse. So over to you, Kayla.

- [Kayla] Thank you so much, Alida. Yes, I am going to be discuss the VVOR and VORS assessments on the ICS Impulse Systems oculomotor assessment protocol. Firstly, let's have a look at VVOR assessments. VVOR stands for visually enhanced vestibular ocular reflex. When this test is conducted, the patient is asked to maintain their gaze on a stationary dot or sticker placed on a wall whilst the clinician moves the patient's head from left to right at a pace of about 0.5 hertz with an amplitude of 10 degrees. Before I can jump into explaining the anatomical pathways stimulated when conducting the VVOR assessment, it is important to discuss the frequency at which the clinician is moving the head, and how this changes the sensitivity of the test for oculomotor pathologies versus peripheral pathologies. It's important to realize that generally when the head is being moved from left to right during a vestibular

assessment, it's assumed that it is a test sensitive to the peripheral function of the horizontal semicircular canals and the superior vestibular nerve. However it is important to bear in mind that the semicircular canals are actually more sensitive to high frequency head movements.

Whilst the visual and the somatosensory systems are sensitive to low frequency head movements. In the head impulse test and the suppression head impulse test, the head is moved at a fast frequency. Thus the response obtained is dominated by the vestibular system. In fact, the visual at the somatosensory systems are actually said to be suppressed when the head is moved at such high frequencies. Contrastingly when conducting the VVOR and the VORS tests, because the head is being moved at a low frequency, about 0.5 hertz, the response elicited is dominated by the oculomotor system. It is therefore viewed more as a test of central vestibular function. Let's have a look at what this means visually when relating it to anatomical pathways. The left diagram represents the tracking and optokinetic pathways. And the right diagram represents the vestibular ocular reflex pathway. Alida has already gone over the pathway of tracking and optokinetics, so we're not gonna go over that here in too much detail. However it is important to note that when you are moving the head below 0.5 hertz or 50 degrees per second, as is done in the VVOR testing, the control of the eye position is mainly dictated by the oculomotor pathways, the diagram on the left. If the head is moved between 50 and 100 degrees per second, a combination of both the oculomotor and vestibular ocular reflex systems controls the position of the eyes.

Lastly, if the head is moved faster than 100 degrees per second, as what is done in the head impulse test, the vestibular ocular reflex controls the eye movements and the oculomotor system is said to be suppressed. All this being said, the VVOR assessment specifically is a test of visual vestibular interaction and is thought to have input from the tracking, optokinetic and central vestibular ocular reflex systems. Therefore it is a sensitive test to central fallout as the patient's ability to complete the test relies on

multiple central pathways and anatomical . It is important to consider the relationship between oculomotor tests such as smooth pursuit, and optokinetic responses in relation to the VVOR. For example patients with most types of genetically-identified spinocerebellar ataxia, sorry, let me start that again.

For example, in patients who, sorry, I'm a little bit lost here, give me a second. Patients with most types of genetically-identified spinocerebellar ataxia, the smooth pursuit and the optokinetic gain responses are low. But VVOR responses can be normal. In contrast, patients with bilateral vestibulopathy have normal smooth pursuit and optokinetic response gaze, but have by definition low VOR resulting in abnormal VVOR. However patients with impaired smooth pursuits and optokinetic responses usually due to cerebellar ataxia produce near-normal VVOR using the vestibulocular reflex. Similarly patients with bilateral vestibulopathy produce a near-normal VVOR below one hertz using their smooth pursuit and optokinetic response systems. Impairment of the VVOR below one hertz therefore indicates double pathology involving both vestibular and cerebellar pathways. This is what the VVOR result looks like. What you see here is a representation of head and eye movements. The orange line represents the head movements and the green line represents the movement of the eye. In a patient with normal central vestibular function, the head movement tracing and the eye movement tracing should lie on top of each other, and no saccades should be present. If the tracings do not lie on top of each other and catch-up saccades are present, the patient may be presenting with a central vestibular pathology.

Okay, next we are now going to move on to discussing the VORS test. VORS stands for vestibular ocular reflex suppression. This module is specific to the ICS Impulse System's oculomotor protocol. VORS cannot be tested using the VNG system. When conducting this test, the clinician again moves the head from side to side at 0.5 hertz with am amplitude of 10 degrees. In this assessment, the instructions to the patients varies from the VVOR assessments. Instead of staring at a dot on the wall, the clinician

will ask the patient to focus on a laser dot which is beaming from the impulse goggles. When the head is moved, the laser dot moves with the head thus requiring the patient's eyes to move in the same direction as the head movements. When moving your head, the vestibular ocular reflex naturally moves your eyes to the opposite direction of the head movement to keep an image stable on your fovea. However, sometimes the vestibular ocular reflex is counter productive because your goal is to view an object which is moving in the same direction as your head movement. Imagine being at the Grand Prix and a formula one car races past and your move your head to follow it and your eyes move in the opposite direction. Definitely not ideal. This is where the vestibular ocular reflex suppression is necessary. In order to achieve this, the tracking system is set to inhibit the vestibular ocular reflex.

Dr. Kamran Barin, who's an expert in the area of balance, wrote an Audiology Online article in 2007 discussing the clinical and experimental observations which have already established a strong association between failure of fixation suppression and smooth pursuit abnormalities in the tracking test. So let's have a look at what this pathway actually looks like. Remember that the head is being moved and the patient is instructed to keep their gaze on the dot that is moving with the head. As you can see at the bottom of the diagram, movement of the head elicits the vestibular ocular reflex to some degree. The tracking system has to suppress this vestibular ocular reflex. Let's discuss how it does this. If you have a look at the diagram, firstly the patient needs to see the target object. In other words, the target image falls on the fovea of the eye. The middle temporal eye field and the medial superior temporal area in the cortex then perceives the visual input and determines the direction and the velocity of the eye movement necessary to suppress that vestibular ocular reflex movement. This inferent information is then carried to the dorsal lateral pontine nuclei where pontocerebellar fibers are subsequently sent to the flocculus and vermis in the cerebellum when execution plan for the correct horizontal eye movements are made. The flocculus then projects information to the vestibular nuclei which then communicates the execution

plan via the medial longitudinal fasciculus to the abducens and oculomotor nuclei which then hopefully successfully suppresses the vestibular ocular reflex. Should the patient not be able to adequately suppress the vestibular ocular reflex, pathology may be present somewhere along this pathway.

Because the neurological pathways are the same, if you were to crosscheck this result with tracking results on the VNG system, you will most likely observe that both tests are abnormal. It is important to note that even though this is a test more sensitive to central pathology, if the patient has a peripheral pathology, this may affect the results of the assessment. If you think about it, in order for the cortex to identify the current speed and direction to suppress the vestibular ocular reflex, it needs to first receive accurate information from the peripheral system about where the eyes are moving to. So it is important to ensure that you have a full battery of tests for crosscheck and correlation purposes, as a faulty peripheral vestibular system may result in test abnormalities not attributed to the central system. Okay, so like you can see here again is a representation of head and eye movements. The orange line representing head movements and the green line representing eye movements. So as you can see here, as the head is moving, the eye remains relatively stable as the eye fixate on the dot ahead of them. You will notice small catch-up saccades enable the eye to suppress the vestibular ocular reflex in order to maintain fixation.

Any abnormalities in the tracking system will result in inadequate suppression and in the results you may see that the eye tracing follows the head tracing. One last thing I would like to mention about the VORS test is that clinically we have observed that it requires less concentration and cooperation from the patients. So it is an easier test to conduct on your difficult-to-test patients or your malingerers. Okay, all right so while we believe that the ICS impulse system is a fantastic tool, as with everything there are some disadvantages that clinicians need to be aware of if they are using the ICS Impulse System to assess both peripheral and central vestibular pathologies. Firstly,

because the ICS impulse needed to be lightweight as to prevent goggle slippage from the head during impulse testing, the ICS impulse only has one camera which only records eye movements of the right eye. This is for the most part not a problem because most pathologies affect movement of both eyes symmetrically. So recording from just one is sufficient. On the other hand though, clinicians may miss pathologies that result in abnormal movement of the left eye.

An example of this would be INO where only the lateral gaze of the affected eye may actually be impaired. This is often caused as a result of pathology at the level of the medial longitudinal fasciculus commonly caused by strokes or multiple sclerosis. Although this is said to be a disadvantage, if we think about it, even when using the VNG system, no abnormal eye movements such as INO should come as a surprise to the clinician as a generally a bedside evaluation of the eyes is conducted beforehand. Here disconjugate lateral eye movement would already have been observed. We may need to ask ourselves the value of continuing with doing oculomotor assessments on either the VNG or Impulse System. At the end of the day, the conclusion from our side would be the same. A central pathology would be suggested, and we would need to refer that patient to a neurologist. Secondly, another disadvantage would be that because the camera is on the right, if a patient has any eye abnormalities on this side, the test cannot be completed on the patient.

For example, if the patient has a droopy eyelid on the right, or if the patient is blind in his right eye, or if the crosshair just cannot stabilize for some reason. Sometimes all the white eye liner, white mascara and tape in the world can't stabilize that crosshair. There with the VNG system, you would just state that it only uses the left eye for data. If you are using the Impulse System, you may not be able to complete the test and would have to rely on other assessments to make your conclusions and recommendations. Thirdly, normative data for the VVOR and VORS test has not yet been established. This means that your results are not summarized and compared to normative data. Results

therefore need to be analyzed subjectively by looking at the tracings. This means that you need more experience in interpretation of results. The fourth point discusses how the head movements is controlled by the tester. For those of you who are familiar with the VNG system to assess tracking, the light moves on the light bar between 0.2 and 0.7 hertz, giving you a range of tracking abilities across different tracking speeds. As we've discussed earlier on, the tracking pathway is assessed using the VORS assessment in the ICS impulse, and unlike the VNG system it requires the clinician to move the patient's head from left to right.

This means that results could vary between clinician testing as one clinician may have moved the head at 0.2 hertz while testing in the other at 0.5 hertz while testing. Abnormality may be seen at 0.5 hertz but not at 0.2 hertz. One also has to be careful that you are not going over 0.5 hertz as this could be, this could result in the peripheral system dominating the response obtained and becoming less sensitive to central pathologies. This problem however is easily overcome with the use of a metronome to guide the clinician's speed. This is available as an app and actually it can be downloaded for free. Lastly, as discussed earlier although minimally stimulated an abnormal vestibular ocular reflex as a result of a peripheral vestibular pathology, can act as a confounding variable and cause abnormalities in your VVOR and VORS assessments depending on how severe or acute the pathology is. This was seen in Ramos and colleagues research conducted in 2018. His research was entitled, "VVOR and VORS testing "as a tool in the diagnosis of unilateral "and bilateral vestibular hyper function" should you wish to read a little bit further. I know this is not a point in the slides, however I would like to mention that it is always important to remember that the tests available on both the ICS systems do not tell you if there is a pathology of the utricle or the saccule. For a full peripheral vestibular assessment, you would also need to add to your test battery. The test also doesn't provide the clinician with the patient's functional ability or way to start in rehabilitation. Other tests such as your dynamic vision acuity would need to be added to your test battery as well. Okay, and moving

over to the advantages of using the ICS Impulse System. Firstly, the ICS Impulse System is portable. All that is required for the assessments are the impulse goggles and your laptop. Unlike the VNG system, there is no light bar or no piece of equipment which the goggles need to attach to. The goggles connect straight to your laptop via USB. This fact is highly convenient and progressive, specifically when considering the vestibular population who are often sickly, in hospital or sometimes so debilitatingly dizzy that they cannot move to get to you. We understand that the best time to assess patients is when they are symptomatic.

However, specifically with peripheral or factuating pathologies, we often end up needing to assess these patients when they are either asymptomatic or in their less acute stages where central compensation may have already started occurring. This makes it more difficult to elicit diagnostic signs. Imagine being able to get in your car and go see your patient wherever and whenever need be. The immobile VNG system has not allowed us to do this in the past. Secondly, the ICS Impulse System enables the clinician to assess the same central pathways as the VNG system. Over and above this, it also enables the clinician to assess the peripheral vestibular system gaining invaluable information on the functioning of all three semicircular canals and the superior and inferior nerves bilaterally. Thirdly, the ICS Impulse System is modular. The modules include video appraisal, VHIT, positional oculomotor and caloric. This means that you're able to purchase different modules at different times depending on the needs of a clinic making it a customizable, practical and cost-effective addition to your equipment.

The fourth advantage is that specifically with peripheral pathologies, results from VHIT testing can monitor central compensation pre and post vestibular rehabilitation. The results help the audiologists to advocate for vestibular rehabilitation and also suggests when therapy can be terminated. This is the only tool in vestibular assessments that provides this. The fifth advantage is that the goggle design is more sleek, light weight

and comfortable for the patient when doing oculomotor assessments. Lastly, one great feature on the ICS Impulse System that the VNG does not have is the ability for the recording of the eye to be played back in slow motion. This makes it much easier for the clinician to identify strange eye movements and identify the fast phase of the nystagmus beats. So as with all audiological tests, no one test is perfect or without its own unique challenges.

And that is why as audiologists, we are always reminded by the experts in the field to make use of the test battery to verify our results. We believe that the deciding factor in choosing between VNG and impulse testing depends on the population to be served, as well as the testing environment. As already mentioned, Impulse allows for mobile testing, testing in hospitals or monitoring sick patients like those receiving chemotherapy. If you are already, if you already have a VNG system the advantage of the Impulse will lie video Impulse Testing, which is not included in the VNG software. If you don't have a VNG system and would like to start serving this vulnerable population, you might consider rather investing in the Impulse System. Thank you so much for lending us your brain today. We truly believe that together and by sharing knowledge we can achieve so much more. This is the process of continuous professional development which we know you believe in. Otherwise you wouldn't have logged in today. Okay, so that concludes our presentation. So let's move into some questions. You are welcome to type your questions. Mary will receive it and then facilitate the questions and answer session. If you do not have time for questions or you think of questions a little bit later, you are welcome to pop us an email as well. But other than that, we wish you well in your balance assessment endeavors. Thank you so much. Mary, over to you.

- [Mary] Thank you so much Kayla and Alida for sharing your expertise in such an easy to follow and informative presentation. I certainly learned something and I'm sure that

our attendees did as well. The first question that I see, is it possible to do caloric testing using the ICS Impulse goggle? That's for either of you to answer of course.

- [Alida] Okay, yes we, especially because it's offers you the option of being more mobile than with your VNG system, you can do this now module release. So it's a module that you can add onto your VNG, sorry, a model you can add onto your ICS Impulse System and it gives you the same information that you would get from your caloric testing on your VNG. What is however very nice on the ICS Impulse System is if you do not your bithermal but monothermal caloric testing that will work out the caloric weakness as well where as on your VNG system, it will work out the bithermal caloric weakness. But if you do monothermal, you have to calculate it manually. So that is a very nice feature.

- [Mary] Thank you, Alida. Another question, what would a patient with oculomotor impairment commonly complain of in a clinical setting?

- [Alida] Okay, so what we find that patients complain of when we see them is mainly blurred vision. We've spoken about diplopia, so that double vision. Also impaired eye movements, difficulty in reading. We have a lot of people complaining about difficulty in reading. Some just say dizziness. We find that dizziness is a very widely used term. Some experience headaches. Definitely ocular pain. And then poor visual base concentration. And we find that especially people we get up in occupational setting or in the classroom.

- [Mary] Well I think that perhaps you've even answered this next question. You talked about several different conditions that can impair the oculomotor function and display abnormal results in that part of the test battery. Can concussion also impair this oculomotor function? I think I just heard you describing many symptoms that are oftentimes encountered with concussion.

- [Alida] Yeah, yes, definitely. Ocular issues like poor eye tracking after concussion is very common. Specifically cranial nerves three, four and six which innervate the eye muscle are susceptible to injury. Anywhere along the route from the brainstem to the eye muscles. So this needs to be assessed and is especially important in people working in the sports field. And I'm glad that question is asked because it also stresses the importance of something that we sometimes forget and that is the cranial nerve assessment as part of the balance evaluation. And what we found is what sometimes happen is everybody knows that the cranial nerve assessment is important but people in the team sometimes assumes that somebody else in the team has actually already done it. So make sure that the patient did receive a cranial nerve assessment. But yes, definitely in concussion.

- [Mary] And you also mentioned the bedside assessment in terms of evaluating the patient for INO, internuclear ophthalmoplegia and looking for conjugate eye movement. But this one question says a lot of clinicians also only access oculomotor function tests manually as a bedside test. And how important is it to utilize equipment as opposed to simply doing bedside testing for tracking and saccades?

- [Kayla] Yeah, so when a neuro objective tool is available, subjective assessments is better than nothing I suppose. But it is much easier to miss pathology if you are just doing a bedside evaluation. If you are for example evaluating saccades, you won't be able to express the result in terms of accuracy, latency and velocity for example. You will only be able to sort of make a subjective comment on what you're observing but won't be able to specifically identify which aspect of the saccades is pathological, which we know is quite diagnostic. You could consider a bedside assessment as a screening procedure I think and assessment using VNG or impulse equipment as more diagnostic.

- [Mary] Perfect, thank you Kayla, yes. And another question. Does the ICS Charter and the ICS Impulse use the same goggle?

- [Kayla] Okay, so they do not use the same goggle. It's a completely different design. The VNG goggle is quite a large goggle whereas the ICS Impulse goggle is much, much smaller. We're going to go back in the presentation just to give you a visual of exactly what the difference is between the two. I think it was right there in the very beginning of the slides. Let's just quickly find it. But yes, obviously because the Impulse goggle was designed for quick movements, it needed to be very lightweight so that it didn't move on the patient's head. So if you think of needing to, for example, do a head thrust on a patient while they're wearing the VNG goggles, it's almost impossible for those goggles not to have quite drastic movements on the patient's face. So there we go. These are our image for that question over there. So you'll see on the left is the Impulse goggle. It fits quite snug on the patient's face. And then the VNG goggle is quite large and heavy and doesn't fit as snug.

- [Mary] Thank you and another question regarding differentiation between the ICS Charter and the ICS Impulse. Does the ICS Charter have any video playback? I know you mentioned there's slow motion with the Impulse and not with the Charter, but is there also playback at all with the Charter?

- [Alida] Yes, so with the Charter VNG System, you can also make a recording. You are slightly limited in terms of there's more limitation in terms of the time of the recording, but you can definitely record it and keep it. And you can also export it, email it to a doctor or anybody for a second opinion. But it is in realtime. So you're not able to view it as a slow motion. Also what is important is that you just have to remember to press the record button at the bottom where in the Impulse system, it will, when you stop the test, it will ask you, do you want to save it, yes or no.

- [Mary] Thank you, Alida. And just to clarify, do you consider smooth pursuit and VORS interchangeable as part of the test battery?

- [Kayla] So yes, these test assessments do assess the same neurological pathways. For example I had a case the other day where in the bedside evaluation, tracking appeared to be perfectly normal. However results were abnormal across frequencies when we were doing the tracking assessment using VNG. So what I then did was assessed VORS and the patient's results were absolutely normal in VORS. So it turns out that patient just so desperately wanted to be diagnosed because she had been through so many medical professionals to get to where she was finally that she was actually purposefully not following the instructions as well with the VNG tracking system. So yes, most definitely, they do assess the same pathway.

- [Mary] So it sounds Kayla, like you're also saying that there is a voluntary, or there's cooperation required for the traditional smooth pursuit test whereas VORS, if I guess cooperation, you have to stay focused on the target, but with that head fixed target, it's very difficult to fake abnormal results, correct?

- [Kayla] Yeah, we have observed that clinically that the VVOR and VORS tests, patients appear to find it a little bit easier. So we find that we can get results a little bit faster using those two assessments whereas when using our VNG equipment, we often need to reinstruct patients and redo assessments. But I guess it's also patient dependence.

- [Mary] Okay, and we have one minute and one question left. And that is, do you really find a difference using the smaller goggles? So does the goggle size really make a difference during testing for the patient?

- [Alida] Okay, so yes, the google for the ICS Impulse System is lightweight. It's a lot more comfortable. And the big thing is that it's unlikely to move during testing, especially when you're changing position. For instance if we're doing the Dix-Hallpike, which we didn't discuss today, but that is part of the test battery, it's really easy to do the recording and it's easy because the goggle doesn't change and you don't need to recalibrate. It is in other words not specifically important for oculomotor testing, but in relation to the full test battery, it definitely makes a difference.

- [Mary] And I'm gland that you mentioned the Dix-Hallpike. Does the ICS Impulse with Dix-Hallpike measure torsional nystagmus as well as the horizontal and vertical?

- [Alida] Yes, which is a clear advantage of the ICS Impulse above the VNG because that is something that was lacking in the traditional VNG battery.

- [Mary] Perfect, and that brings us to the end of our hour, one minute over, perfect timing everyone. And thank you to all the participants. Everyone remained in the classroom for the Q and A, which is fantastic. And thank you on behalf of Audiology Online and Natus Medical, and thank you to our presenters, Alida and Kayla. And this will end our meeting today. Thank you so much.