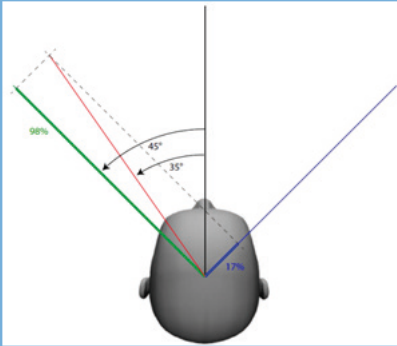# 1. General

Question	Answer
Why is ICS Impulse superior to Visual Observation?	• ICS Impulse can identify covert saccades • Validates that the head impulse is performed properly • Both sensitivity and specificity are 95% for ICS Impulse. Sensitivity is estimated at 70% for visual observation* • Reduction in false negative (identifying patients as normal who are truly abnormal) • Objective Analysis with age-based normative data • Documented head impulse test results • Better patient comfort during testing because smaller head impulses can be used (150 -200 deg/s) with superior diagnostic accuracy. *Weber KP, Aw ST, Todd MJ, McGarvie LA, Curthoys IS, Halmagyi GM. Head impulse test in unilateral vestibular loss: vestibulo-ocular reflex and catch-up saccades. Neurology 2008; 70(6):454-463.*
How is Head Impulse testing similar and different from Caloric testing?	**HIT** • Side of Lesion specific • Detects abnormalities in all six semicircular canals in cases with peripheral vestibular loss (Lateral, Anterior and Posterior) • Tests with stimuli replicating the patient's everyday situations (physiological stimulus) • Stimulus does not persist between tests • Ability to test patients even if they have middle ear disorders • Ability to test patients who do not tolerate calorics (young children, elderly, acute patients, or patients with severe hearing loss) **Caloric** • Ear-specific • Detects cases of peripheral vestibular loss in Lateral semicircular canal • Tests at Low Frequencies (~0.025 Hz) • Stimulus can persist between irrigations especially if not performed properly • Middle ear disorder may prohibit performing the test • Some patients will not tolerate caloric testing or will not allow the caloric test to be completed
We know that for caloric tests, if a patient is tired during the measurement or even asleep (which never should happen), then there is an impact on the test results. The patient must be awake and at a similar awake state for all measurements (warm and cool). Is this the same for vHIT?	No because vHIT is closer to a pure three neural arch reflex to the eye versus the caloric which is strongly centrally mediated.

2. Data Collection

Question	Answer
How does Impulse assist in performing proper head impulses and making sure only quality data is analyzed?	Performing a proper head impulse is important in order to properly diagnosis the patient. Impulse displays training curves that assist in demonstrating how a good head impulse looks. The operator feedback tells you if the head impulse is good or poor. If it is poor it tells you why: too slow, too much overshoot or wrong planes stimulated. For LARP/RALP the head position feedback ensures that the head is properly turned the correct amount of degrees to isolate the canals which are being tested. There are also 2 algorithms that assess if the head impulse is properly performed. If it is not then the head impulse will be rejected. The analysis algorithm looks at both the head and eye movement. If the patient is not staring at the fixation dot the head impulse will be rejected. All of these features ensure that only quality data is represented in the analysis. This increases your comfort in providing a proper diagnosis.
Why is it important to calibrate each patient? Why should default calibration only be used if the patient cannot be properly calibrated?	If possible you should **always** perform calibration. If the patient cannot see the laser calibration dots or cognitively cannot perform the task take the default calibration values. Remember, the patient has to be able to see the fixation dot or stare at something during the test. Default calibration △ value is = 21. Based on 25 patients range 24-51 (left) and 42-73 (right). By using the default calibration, you could be introducing as much as 10% variability to the data collection results. This is why it is important to calibrate the patient if possible; however, this variability is better than not being able to test at all. *See reference manual appendix 1 for more information regarding calibration.*
Why is performing unpredictable head impulses important? Why do we not want the patient to be able to anticipate the head impulse?	We do not want the patient to try to compensate for their disorder. Randomizing head impulse direction mainly affects the catch-up saccade pattern. If the head impulses are completely predictable, patients will do better in making covert saccades (compensating). In order to show the deficit (which is the purpose of the test), it's better to randomize the order.
Why collect varying velocities?	Recording of different velocities was interesting from a scientific point of view, because it told us that velocities of about 150-200 deg/s for lateral head impulses and 100-150 deg/s for LARP/RALP are necessary to detect a unilateral deficit reliably. The only reason for different velocities in clinics is that the 3D plots look much nicer.
What is the best velocity to use during testing when trying to identify unilateral deficits reliably?	150-200 deg/s for lateral and 100-150 deg/s for LARP/RALP . The lower limit is based on the following publication (figure 2). Head impulse test in unilateral vestibular loss: vestibulo-ocular reflex and catch-up saccades. Weber KP, Aw ST, Todd MJ, McGarvie LA, Curthoys IS, Halmagyi GM. Neurology. 2008 Feb 5;70(6):454-63. MacDougall HG, McGarvie LA, Halmagyi GM, Curthoys IS, Weber KP (2013) The Video Head Impulse Test (vHIT) Detects Vertical Semicircular Canal Dysfunction. PLoS ONE 8(4): e61488. doi:10.1371/journal.pone.0061488. The upper limited was based on experience from the team in the article. The more vigorous the head impulse, the more likely you will get bumps & artifacts with a video goggle system.
Why should the patient be 1 meter from the fixation dot?	Having a very close target activates convergence, i.e. the eyes have to cross in order to look at the dot. Activation of the convergence system may interfere with the VOR. In addition, a close target adds a linear component, i.e. the eyes moves sideways relative to the dot (this effect becomes smaller with increasing distance of the target). From a technical point of view, there may be some parallax of the laser (relative movement of the laser dot in the field), because it is attached to the right side of the goggles. Therefore it is a good idea to have at least 1 m of distance.
What happens if the frame rate drops below 219?	If the frame rate drops below 219 during data collection the software will reject that head impulse. A frame rate below 219 is problematic because the data collection will not be accurate (e.g. peak velocity, gain measurements etc).
How many head impulses should I perform?	The default is 20. This was recommended by Drs. Halmagyi and Curthoys as a starting point. Once the tester is confident in their ability to perform proper head impulses with very few rejects then this number can be reduced.
Can you test a patient that has Strabismus?	Yes, as long as it's not a paralytic strabismus. You need to cover one eye (the one that is not recorded) to make sure the patient is always fixating with the same eye.
Why do we not tilt the head for head impulse testing so that the semi circular canals will be straight like when one walks. Should we tilt the head to compensate for the angle of the canals?	The horizontal canal planes are pitched up just a little in the head (by about 21 degrees - Curthoys et al 1977). So to get them exactly horizontal you would have the head pitched down by 21 degrees. But it does not really matter because the strength of the stimulus decreases as a cosine function of head pitch. So being 20 degrees off has hardly reduced the strength of the stimulus to the horizontal canals. *For more information please read and see Figure 2: Curthoys I.S., Blanks H.I. & Markham C.H. (1977) SEMICIRCULAR CANAL FUNCTIONAL ANATOMY IN CAT, GUINEA PIG AND MAN Acta Otolaryngol 83: 258-265.*
For LARP/RALP, why do we recommend the head to be moved to 45 degrees to the right/left? And why should gaze be fixated on the fixation dot placed straight ahead in front of the patient's body? 	First why do we move the head 35 to 45 degrees? In doing so we align the plane of the canals that we are testing with the fixation dot, this allows for the head impulse to be performed using a pitch movement. It is much easier to perform the head impulse using this pure pitch movement and properly stimulate only the canals intended to be tested. Second why do we have the patient's gaze directed back at the fixation dot positioned directly in front of their body? We want to make sure that the gaze is in the plane of the canal when the head impulse is performed. Aligning the gaze with the plane forces the eye movement to be purely vertical*. This makes the response one that we can actually measure. If you have the person look toward their nose and NOT in the direction of the plane being tested the eye movement will be a portion torsional and a portion vertical. We cannot currently measure torsional eye movements at 250Hz. In order to measure torsion we would need 20x the resolution (larger image and higher resolution) and more computer power to process the information. If we went to a higher resolution to measure torsional, we would reduce the frame rate to 60 Hz. A frame rate of 60 Hz is too slow to identify catch-up saccades. We have optimized the procedure to be able to perform the head impulse with goggles and accurately identify the presence of catch-up saccades. The normative data are based on the recommended procedure and any deviation from this recommendation would require collecting new normative data. *For more information please read: Migliaccio AA & Cremer PD (2011) The 2D modified head impulse test: a 2D technique for measuring function in all 6 semicircular canals. J Vestib Res 21(4):227-34.* *Leigh A. McGarvie, Marta Martínez López, Ann M. Burgess, Hamish G. MacDougall & Ian S. Curthoys Horizontal eye position affects measured vertical VOR gain on the video Head Impulse Test Frontiers in Neurology http://journal.frontiersin.org/article/137078/abstract*

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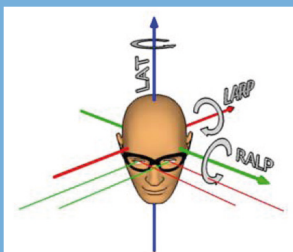
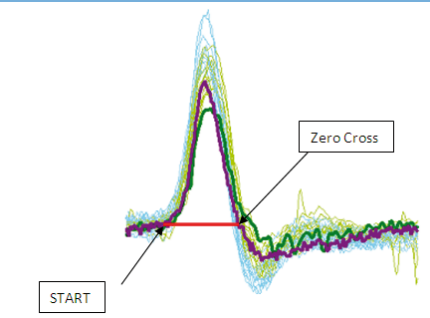| Head Position Feedback: What degrees are the yellow and green? Why were these degrees chosen?	The head position feedback color changes based on the position of the head. The center button determines the 0 point or your reference point. For accurate measurements, the patient's head should be facing straight at the fixation dot and not moving when the center button is clicked. The settings are: 35 to 39.9 degrees displays yellow, 40 to 46.9 displays green and 47 to 49.9 displays yellow. Any other degree will display gray.
	The head position feedback is a guide to help you position the patient's head in the optimal range. The head has to be at a minimum of 35 degrees in order to test LARP/RALP. A head impulse at 35 degrees still stimulates a canal (positioned at 45 degrees) with about 98% effectiveness. The problem is that a head impulse at 35 degrees will also stimulate canals in the opposite testing plane (the one you are not testing) with about 17% stimulus magnitude which is significant. The proportion of the response from the canals you are trying to test rolls off slowly (cos) but the proportion of the response from the non test canals rolls off quickly (sin).
	Cos of 10deg (the offset between the red and green planes) = 0.98, and sin of 10deg = 0.17 For example an impulse at 30 degrees stimulates these test canals at 97% effectiveness and the non-test canals at 26% magnitude, and at 25 degrees it is 94% effectiveness and 35% magnitude which would make it difficult to interpret the results and determine side of lesion.
	In this example delivering a 200deg/s peak head velocity impulse in the 35 deg (red) plane would stimulate the LARP canals with a peak velocity of 196deg/s and the RALP canals with 34deg/s. Head impulses at angles less (or more) than the target 45deg still produce similar stimulation of the tested canals but they also start to stimulate canals that you are not trying to test and that's why testing with the head as close to 45 deg is ideal. This is all based on the assumption that the patient's canals are aligned with these planes at 45 deg. Please see Blanks RHI, Curthoys IS & Markham CH (1975) Planar Relationship of the Semicircular Canals in Man Acta Otolaryngol 80:185-196.
	Remember 35 degrees is the minimum and 45 degrees the ideal angle for performing LARP and RALP. Watch the real time trace. Only the head trace which is in bold (the one you are testing) should be moving. The other 2 should remain fairly flat. If both the blue and pink head traces are moving you have moved the patient's nose toward the center or are performing your head impulses toward the nose, and the canals are no longer isolated. If this is occurring you will see an orange light in the operator feedback and the message will display "Wrong planes stimulated".

3. Data Analysis

Question	Answer
What is the difference between overt and covert catch-up saccades?	• **Overt** – occur after the head movement and can sometimes be seen using visual observation • **Covert** – occur during the head movement and cannot be seen using visual observation
Where did the default normative data cutoffs come from?	When Impulse was first released we utilized the published lateral data previously collected by our Australian collaborators at University of Sydney*. Based on this data 0.6 was the appropriate choice. MacDougal HG, Weber KP et al (2009) The video head impulse test: Diagnostic accuracy in peripheral vestibulopathy. Neurology 73:1134-1141.
	During the process of preparing the OTOSuite Vestibular software for release we had to determine what the cutoff between "normal" and "unilateral loss" overlay on the gain graph should be for LARP/RALP. In doing so, we decided to relook at the data for Lateral as well. We collected data for all 6 canals on a larger dataset of 29 normal subjects and sent the data to Ian Curthoys for analysis. It was determined that a cutoff between "normal" and "unilateral loss" overlay on the gain graph of 0.8 is more appropriate for lateral. The cutoff for LARP/RALP was is at 0.7 The cutoff between "unilateral loss" and "bilateral loss" of 0.1 overlay on the gain graph did not change.
	In 2015 we released age-based normative data for ages 10-99 years old. McGarvie L, Halmagyi M, Curthoys I, MacDougall H. Video head impulse testing – age dependent normative values in healthy subjects. XXVIII Meeting of the Bárány Society, Buenos Aires, Argentina, 25-28 May, 2014. Journal of Vestibular Research 24 (2-3), 77.
What is the difference between the collection and analysis data?	These are 2 completely separate algorithms. The collection algorithm is on-line (during data collection) and less detailed. These are the numbers that display in the collection window (left/right accepts and rejects) and is displayed in the collection column in the test info window. All the data (not just the accepted collection data) goes thru a second algorithm - the Analysis algorithm and this is more detailed and off-line and the results are displayed in the analysis column in the test info window and what is included in the 2D and 3D analysis. The numbers for the collection and analysis may not always add up to the same number because the raw data is being analyzed twice by 2 different algorithms. *See the reference manual appendix 2 for more information.*
Why would the collection number be larger than the analysis?	Due to the way impulses are found (peak detection in analysis vs velocity threshold in collection), if the operator performs an impulse with a peak of around 50deg/sec, this impulse will be counted by collection, but may not be counted by analysis.
Why would the analysis number be larger than the collection?	Collection impulses are 250 samples and analysis impulses are 175 samples, there is a small window whereby if you perform two impulses quickly between 100 and 200 samples apart, the collection code will see this as one impulse, and the analysis code might see it as two impulses. It is important to perform the head impulse wait and look to verify that your head impulse matches the training curve and the operator feedback is green.
Why am I getting high gain values?	High gain values could be one or a result of a combination of the below issues.
	1) Slippage of the goggles - make sure strap is very snug, that the cable from the goggles is clipped to the patient's right shoulder or collar with some slack, and there are not gaps between the foam cushion and the patient's face. See section 3.4 of the user guide for pics of a good and poor goggle placement. You can also access the reference manual from the bottom left corner of the software. Do not touch the goggles or strap when performing head impulses.
	2) Patient is too close to the fixation dot - If they are closer than 1 meter you will see increased gains due to convergence of the eyes. VOR gains will go up with close distances. Never stand in front of the patient and have them fixate on your nose when using ICS Impulse. This method of testing will result in higher gains.
	3) If you have ruled out 1 & 2, it could be that the patient has Meniere's. See Manzari et al. Rapid fluctuations in dynamic semicircular canal function in early Meniere's disease Eur Arch Otorhinolaryngol 14 Dec 2010.

Gain vs 3D Tracing – What should I look at?	BOTH! Do not only rely on the gain graph to determine if the patient is within normal limits or has an abnormal VOR response. You must look at the traces. It is easier to see catch-up saccades in the 3D analysis. If the gain is in the normal range but the 3D analysis clearly shows catch-up saccades then the patient is exhibiting an abnormal response. This is sometimes seen with patients where their covert saccades are right on top of the peak velocity of the head trace. *See blog posts and analysis video at www.headimpulse.com to learn more.*
We tested a patient with right vestibular neuritis but the gain was normal on the left side. Why is this?	This is often seen and has been documented in published articles. The VOR gain to the healthy side does decrease a bit but the normal range is large so you don't detect that decrease. In Manzari L, Burgess AM, MacDougall HG, Curthoys IS Objective verification of full recovery of dynamic vestibular function after superior vestibular neuritis. Laryngoscope; 2001: Rapid Communication. In this article a patient when in attack the VOR gain for the healthy side is ~0.8 (still in the normal range), but on recovery the VOR returned to ~1.0.
Why do catch-up saccades sometimes occur on the "normal" side?	For patients with unilateral vestibular lesions, eye velocities do not match the head velocity for head impulses toward the impaired side (side of lesion). This is due to the asymmetry between excitatory and inhibitory responses of hair cells with the excitatory responses having a greater dynamic range compared to the inhibitory responses. In individuals with a normal functioning vestibular system, this asymmetry is inconsequential because for any head movement, at least one labyrinth can accurately represent the head velocity. In patients with unilateral vestibular dysfunction, the excitatory response is either absent or reduced during the head impulses toward the side of lesion. As a result, the eyes fall behind and a catch-up saccade is generated. On occasions, one may see catch-up saccades for head impulses toward the intact side. The reason for the presence of catch-up saccades for both directions is related to the loss of inhibitory response from the impaired side during head impulses toward the intact semicircular canal. Although the consequences are not as significant as the loss of excitatory response during head impulses toward the damaged side, the effect can still be observed in the form of catch-up saccades and reduction of gain.
Why are gains for head impulses to one side higher than to the other side?	There can be many reasons for that. First make sure the head impulse velocites delivered to the two sides were similar. The gain of each side can be affected by factors affecting just that labyrinth. There will be natural variations. Another reason is since the data is recorded only from the right eye, it is slightly biased (gains are higher on the right than on the left). Ian Curthoys calculated the asymmetry ratio for 90 healthy subjects (data collected by Manzari with prototype and unpublished) and found that the difference was very small 2.7%. This difference was reported in coils (Prog Brain Res. 2008; 171:195-8. Inter-ocular differences of the horizontal vestibulo-ocular reflex during impulsive testing Weber KP, Aw ST, Todd MJ, McGarvie LA, Pratap S, Curthoys IS, Halmagyi GM). In coils the difference was reported at 15%. It is hypothesized that the slower velocity head impulses used with goggles results in a lower difference between leftward and rightward head impulses. This effect most likely arises from physiology.
How is Gain calculated for ICS Impulse? 	There are 175 samples per analyzed impulse. We take each sample from the start to the zero-cross for the head movement. We sum the amplitudes of each of these samples. This gives us one value for the head. We repeat the process for the eye movement giving us one value for the eye. **Gain = eye-sum divided by the head-sum.** Note that for the sake of this calculation, the eye tracing is first de-saccaded. In summary, our present gain calculation is based on area under the (de-saccaded) eye velocity vs area under the head velocity. *MacDougall HG, McGarvie LA, Halmagyi GM, Curthoys IS, Weber KP (2013) The Video Head Impulse Test (vHIT) Detects Vertical Semicircular Canal Dysfunction. PLoS ONE 8(4): e61488. doi:10.1371/journal.pone.0061488*

4. Data Files

Question	Answer
Can I export data in a format I can use for research?	Yes, you can export patients and choose ASCII Test Results or ASCII Raw Data. ASCII Test Results exports the accepted data shown in the analysis windows. ASCII Raw Data exports all data collected even the data rejected by the collection and analysis algorithms. *See reference manual appendix 3 for more information.*
How large are the video files?	See Ch 4 in the reference manual Video Record/Playback for detailed information on eye video, room video, and combined video sizes.