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Video Head Impulse Test: a look at its current use.

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Abstract:

Introduction: The video head impulse test (vHIT) is an innovative test which is able to identify the overt and covert saccades and study the gain of vestibulo-ocular reflex (VOR) of each semicircular canal. The objective of this study was to review different diseases that affect semicircular canals (SCC) and the use of vHIT as a diagnostic tool.

Material and methods: In the pubmed database, articles that defined vHIT were searched, compared vHIT with another clinical test, and studied the efficacy of vHIT in vestibular disease. We found 248 articles published from the last 5 years, were reviewed 63 articles, of which 33 were selected in our work for not meeting our criteria. All articles studied the vHIT in English up to February 2020 were included in the review.

Results: vHIT is physiological quick test, it studies the VOR at high frequency of each semicircular canal by calculating the ratio between the head impulse and gaze deviation. vHIT was more sensitive than clinical head impulse test (cHIT), especially in patients with isolated covert saccades. vHIT test is a vestibular weakness diagnostic test by measuring gain reduction and the appearance of overt and covert saccades. When results shown no alterations, caloric test is mandatory to rule out a peripheral causes of vertigo.

Conclusions: After making a review of different research papers, we conclude that vHIT is a tool that allows us to effectively approach the diagnosis of diseases of the vestibular system, being compared with multiple studies. The functional head impulse test (fHIT) detects more abnormalities than vHIT, but both techniques show a correlation with the Dizziness Handicap Inventory (DHI) score.

Keywords: Video head impulse test; vestibulo-ocular reflex; Vestibular disease; vHIT; VOR.

Abbreviations:

AICA, anterior inferior cerebellar artery; BVL, bilateral vestibular loss; cHIT, clinical head impulse test; ; cVEMP, cervical vestibular-evoked myogenic potentials; DHI, Dizziness Handicap Inventory; EH, endolymphatic hydrops; fHIT, functional head impulse test; ; hVOR, horizontal vestibulo-ocular reflex; ILPC, Isolated loss of posterior semicircular canal; ieMRI, inner ear gadolinium-enhanced magnetic resonance imaging; LSC, lateral semicircular canal; MD, meniere's disease; oVEMP, ocular vestibular-evoked myogenic potentials; PCS, posterior circulation stroke; PICA, posterior inferior cerebellar artery; SCC, semicircular canals; SVN, superior vestibular neuritis; vHIT, video head impulse test; VOR, vestibulo-ocular reflex; VOG, video-oculography; VM, vestibular migraine; VN, vestibular neuritis; VS, vestibular schwannoma.

Highlights:

1. The video head impulse test (vHIT) is an innovative test which is able to identify the overt and covert saccades.
2. Is a physiological quick test, it studies the VOR at high frequency of each semicircular canal.
3. vHIT was more sensitive than clinical head impulse test (cHIT), especially in patients with isolated covert saccades.
4. Is a tool that allows us to effectively approach the diagnosis of diseases of the vestibular system, being compared with multiple studies.

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1.Introduction

In the inner ear, the vestibular system is the apparatus that allows stable vision during impulses or movements of the head. The semicircular canals are part of the vestibular system they provide the sensory information; being sensitive to angular stimulation. Semicircular canals in the peripheral vestibular system and ocular motor nuclei in the brainstem and the extra-ocular muscles are the anatomical components that participate in the vestibular oculomotor reflex (VOR). (1)

The head impulse test is a passive, unpredictable, and high-acceleration head movement with amplitude 10°–20°, with these movements it is possible to evaluate the VOR and his gain; that is the ratio of slow phase compensatory eye velocity. (1) (fig.1)

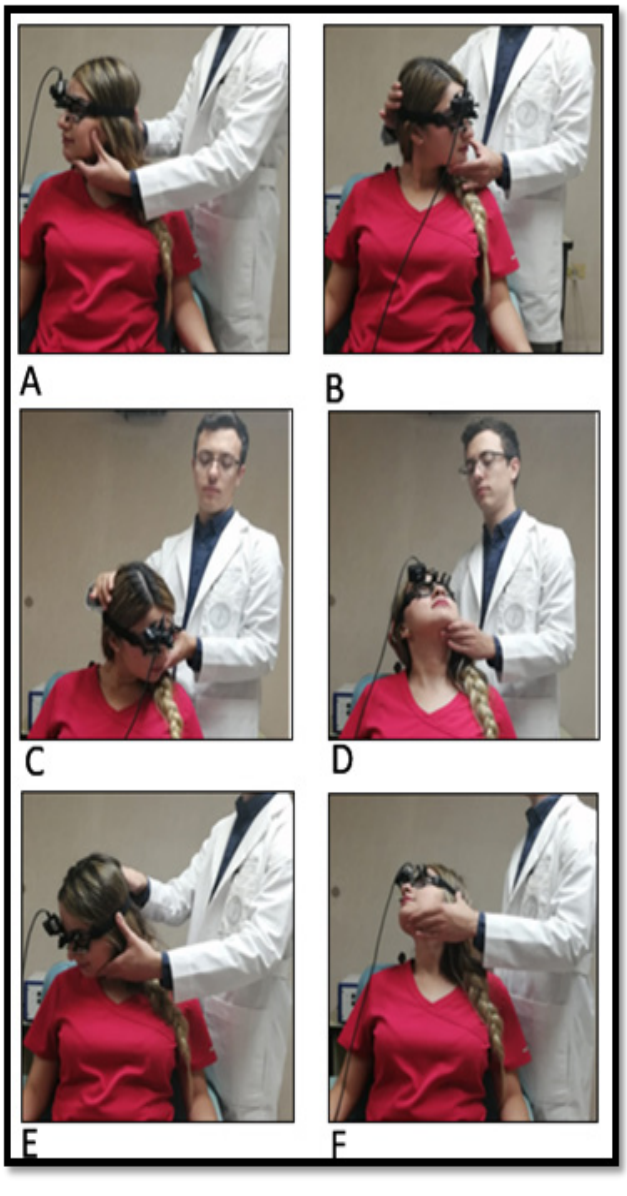

Fig.1 The vHIT. A. Right lateral semicircular canal The examiner stands behind the patient and performs passive movements of the head on the right horizontal plane. B. Left lateral semicircular canal The examiner stands behind the patient and performs passive movements of the head on the left horizontal plane. C. Right anterior semicircular canal: on the horizontal plane the examiner moves the head 45 degrees to the left; Performing the head impulse 15 degrees anterior. D. Left posterior semicircular canal: on the horizontal plane the examiner moves the head at 45 degrees to the left; Performing the head impulse 15 degrees posterior. E. Left anterior semicircular canal: on the horizontal plane the examiner moves the head 45 degrees to the right; performing head impulse 15 degrees anterior. F. Right posterior semicircular canal: on the horizontal plane the examiner moves the head 45 degrees to the right; performing the head impulse 15 degrees posterior.

The VOR can stabilize images in the retina during head movement or impulses by moving the eyes in the opposite direction of the head at the same velocity, keeping an image on the center of the patient's visual field. (2)

The video head impulse test (vHIT) assesses the behavior of the vestibular-oculomotor reflex using a video-assisted recording of the impulse maneuver. It reflects as output a gain value reflex (VOR) as the ratio of a measure of eye movement to the corresponding head movement. (2)

vHIT gains differ in normal subjects depending on the device and method of analysis used, suggesting that it is advisable that each device has its own normal values. Gain calculations that compare the areas under the velocity curve of the head and eye movements during head movements showed the smallest variance. (2)

Normal VOR gain is close to 1.0, patients with unilateral vestibular loss have a reduced VOR gain during the head turn to their affected ear (usually less than 0.7) and their slow phases do not compensate for head turn, with the result that their eyes move with the head, and they need to make corrective saccades for head impulses toward their affected ear, thus identifying the side of loss. Since 2009, the method took up by most of the dizziness clinics around the world, vHIT has supplanted caloric testing as the initial and some cases the final choice in patients with suspected vestibular disorders. (3)

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2.Material and methods

In the pubmed database, all articles that defined vHIT were searched, compared vHIT with another clinical test, and studied the efficacy of vHIT as diagnostic tools with vestibular disease. Using the Pubmed database, we found 248 articles published from the last 5 years, were reviewed 63 articles, of which 33 were selected in our work for not meeting our criteria. All articles studied the vHIT in English up to February 2020 were included in the review (Figure2).

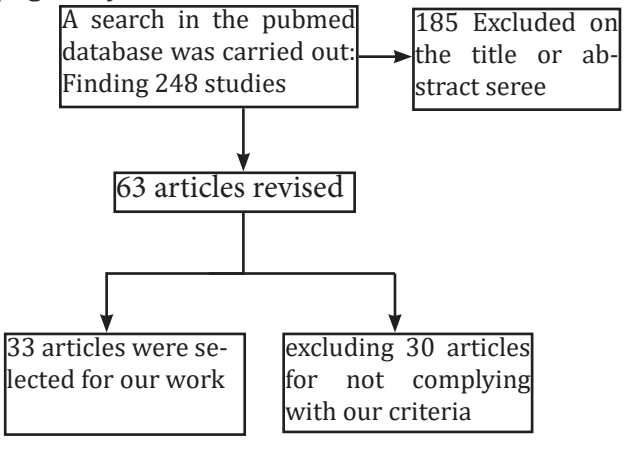

Fig.2 Flow diagram showing stages of article selection.

Our review studied the use of vHIT in different pathologies, such as Meniere's disease, central vestibular disorders, superior and inferior vestibular neuritis, bilateral vestibular loss etc. Which are listed below.

3.Pathologies

3.1 Posterior Circulation Stroke

Central vestibular disorders are caused by lesions in the vestibular pathways, which include vestibular nuclei in the brainstem, ascending projections in the medial longitudinal fasciculus, vestibulocerebellum, thalamus, and parieto-insular vestibular cortex. Clinical manifestations include vertigo, imbalance, and localized neurological deficits. Lesions vary in nature, but may be due to acute ischemia, demyelination, and metabolic disorders. (4)

In published research articles employ either search coil and/or video-oculography (VOG) to record HIT in central vestibular disorders. Search coil is the gold standard in eye movement recording but is semi-invasive and non-portable. In contrast VOG has inferior spatiotemporal resolution but is non-invasive and portable.

For the acute vestibular syndrome, vHIT gain can differentiate vestibular neuritis (VN) of posterior circulation stroke (PCS) with sensitivity of 88% and specificity of 92%, that is comparable to clinical head impulse test (cHIT).

Mantokudis et al. demonstrates a spectrum of horizontal VOR gain and compensatory saccade abnormalities in different subgroups of PCS compared to VN. In contrast to unilateral gain deficit and corresponding large compensatory saccade amplitude, PCS involving the anterior inferior cerebellar artery (AICA) territory (AICA stroke) leads to more symmetric bilateral VOR gain reduction and smaller saccades, while posterior inferior cerebellar artery (PICA) territory PCS (PICA stroke) leads to symmetrical mild reduction in VOR gain with smallest saccades. (5)

PICA strokes were associated with tightly clustered consistently normal HIT VOR gains on both sides without VOR asymmetry only 5% of individual HIT gain values were less than 0.80. The AICA population mean (0.79) was intermediate between the normal (PICA, contralesional neuritis) and abnormal (ipsilesional neuritis) VOR gains. (5)

3.2 Superior Vestibular Neuritis

The VN is the most common cause of acute spontaneous vertigo, is ascribed to acute unilateral loss of vestibular function, probably due to reactivation of herpes simplex virus in the vestibular ganglia, preferentially involves the superior vestibular labyrinth and its afferents. Accordingly, the function of the posterior semicircular canal and saccule, which constitute the inferior vestibular labyrinth, is mostly spared in VN. (6)

Versino et al. conducted a comparative study in a group of 27 VN patients between the results of functional HIT (fHIT), vHIT and Dizzines Handicap Inventory (DHI) questionnaire. Both the vHIT and fHIT exams correctly classified all patients as abnormal on the affected side, when tested in the acute phase. (7) In a longitudinal prospective study, between caloric test and vHIT, Redondo-Martinez et al. found a main horizontal gain of 0.50 and 0.73 in the control after 3 months. (8)

The most frequently encountered clinical pattern of unilateral vestibular loss is superior vestibular neuritis (SVN). These patients

often present with an acute vestibular syndrome and spontaneous horizontal–torsional nystagmus beating toward the healthy side. The vHIT-applicable directly in the emergency room-reveals loss of lateral and anterior canal function with sparing of the posterior canal, making the diagnosis of SVN. In addition to the classic horizontal catch-up saccade upon rotation of the head toward the affected side. Patients suffering from SVN present vertical downward eye movements during head impulse test performed in the yaw plane towards the healthy side, followed by an oblique upward catch-up saccade. (9)

3.3 Inferior vestibular Neuritis

In the inferior vestibular neuritis only the posterior canal is affected, often associated with tinnitus and hearing loss and saccular deficits measured with cervical vestibular-evoked myogenic potentials (cVEMP). (10,11)

As there is short-time spontaneous nystagmus and normal caloric response, these do not fulfill the criteria of classic VN and may be mistaken as a central vestibular disorder. In these cases, detection of posterior canal loss in vHIT may help differentiating between a peripheral and central vestibular disease.

3.4 Bilateral Vestibular Loss with Anterior SCC Sparing

The bilateral vestibular loss (BVL) is a rare cause of visual disturbance (oscillopsia) and imbalance which the most common cause is iatrogenic-gentamicin ototoxicity. Treatment is largely supportive. Care should be taken avoiding suppressing vestibular function medications, and to encourage vestibular activity. (12)

On the clinical practice, the diagnosis of BVL is often delayed or missed, because the characteristic symptoms of postural imbalance and oscillopsia often without vertigo are not recognized. (13) Once the suspicion has been made, the clinical diagnosis is often based on three simple clinical bedside tests: the HIT, dynamic visual acuity, and the Romberg test on rubber foam. (14) With the advent of vHIT, it is now possible to routinely assess the function of all six semicircular canals (SCC) independently. (15)

Based on these investigations, characteristic patterns of SCC hypofunction started to emerge in patients with BVL: anterior SCC function was selectively spared in about 60% of these patients. As it turned out, anterior canal sparing, determined by gain values (>0.7) and cumulative catch-up saccade amplitudes (<0.73°/trial), lower values were associated with aminoglycoside vestibulotoxicity and Menière's disease. In patients with suspected BVL they recommend quantifying vHIT gains and saccade amplitudes for all semicircular canals as the pattern of canal hypofunction may help identifying the underlying disorder. (16)

3.5 Unilateral and Bilateral Loss of PC Function

Isolated loss of posterior semicircular canal (ILPC) function was found in about 2% of patients with vHIT assessment of all six SCC. Complete vestibular work-up, including ocular vestibular-evoked myogenic potentials (oVEMP) and cervical vestibular-evoked myogenic potentials (cVEMP) for testing otolith function, as well as audiograms to assess cochlear function, revealed associated vestibular deficits in more than 80% of these patients. These associated deficits were most frequent in patients with vestibular Schwannoma or a history of VN and often the patients were at risk for concomitant benign paroxysmal positional vertigo.

The oVEMPs were ipsilesionally abnormal (i.e., asymmetry ratio >30%) in 20/40 cases(50%; asymmetry ratio=60±23%) with unilateral ILPC. This included six cases with bilaterally absent responses on oVEMPs. In patients with bilateral ILPC, no cases with bilaterally absent oVEMPs were noted, while oVEMPs were unilaterally impaired in two cases. Significant ipsilesional impairment of cVEMPs (i.e., asymmetry ratio >30%) was noted in 16/40 cases (40%; asymmetry ratio=72±29%) with unilateral ILPC. For bilateral cases, both unilaterally reduced (3/12) and bilaterally absent (1/12) cVEMPs were noted.

While for the anterior and horizontal gains were well above the cut-off, they were decreased (i.e., below the cut-off of 0.7) for the ipsilesional posterior SCC. Likewise, cumulative saccade amplitudes were increased for all three subgroups, for the affected posterior SCC(s), being clearly above the predefined cut-off of 0.73°/trial. They did not identify an effect of the underlying diagnosis on the average gain

(df=4, Wald chi square=3.768, p=0.438; generalized linear model) or cumulative saccade amplitude (df=4, Wald chi-square=4.386, p=0.356) of the affected posterior SCC. (17)

3.6 Vestibular Schwannoma

Vestibular schwannoma (VS) is a benign, usually slow growing tumour of Schwann cells of the superior or inferior divisions of the vestibular nerve (also known as acoustic neuroma). With growth, it compresses neurons within the vestibular nerve, may compress the internal auditory artery and the cochlear nerve, causing unilateral vestibular deficits, auditory dysfunction, including tinnitus. Caloric testing has been the most common method employed to measure the VOR in those with VS. However, this is a time consuming and uncomfortable method.

In a prospective study, Tranter-Entwistle et al. found that caloric testing is close to be equivalent to low frequency rotational testing, e.g. 2–4Hz. In contrast, the vHIT tests the high frequency range of the VOR, e.g. 5–7Hz. There was a statistically significant relationship between the results of the tests previously mentioned, but the limited strength of this relationship suggests that, for unilateral vestibular schwannoma both may provide complementary information on vestibular function. The correspondence between the results of caloric testing and the vHIT has often been inconsistent. (18)

Blödow et al. conducted a retrospective study of 69 participants (39 females, 30 males, age 27–86 years) with untreated unilateral VS. They defined abnormal vHIT gain to the lesioned side as <0.79, abnormal asymmetry as >8.5%, and abnormal caloric ratio as >25%. They found an abnormal ipsilateral vHIT gain in 36% of participants, an abnormal vHIT gain asymmetry in 44%, and abnormal caloric results in 72%. The tumour grade was related to the caloric results, but not the vHIT results. (19)

Batuecas-Caletrio et al. conducted a retrospective study of 50 patients with unilateral VS and found that the caloric test was abnormal in 31/50 (62%), while the vHIT in the ipsilateral side was abnormal (i.e.<0.8) in 27/50 (54%). The caloric and vHIT gain asymmetry results were significantly related to tumour size. (20)

3.7 Ménière's disease

Meniere's disease (MD), characterized by recurrent vertigo attacks, fluctuating hearing loss, and unremitting tinnitus, is a common disease, with an incidence of 15-50 per 100,000 people. The otopathology in MD due to endolymphatic hydrops (EH) was first revealed in 1938 through temporal bones studies. Since then, EH has been used as a histologic marker for MD, the glycerol test, the electrocochleogram, the furosemide test and inner ear gadolinium-enhanced magnetic resonance imaging (ieMRI), have been established as diagnostic methods for EH. (21–27)

Blödow et al. in a comparative study found that the caloric test was abnormal in 67% of patients with MD and in 22% with vestibular migraine (VM) (p=0.002), while the vHIT showed a horizontal vestibulo-ocular reflex (hVOR) deficit in 37% in MD and 9% in VM (p=0.025). In MD, the mean gain vHIT was lower on the affected side than on the unaffected side (0.83±0.2 vs 0.95 ±0.16, p=0.03). In abnormal cases mean gain vHIT values were further reduced to 0.60±0.11 in patients with MD and to 0.73±0.04 in those with VM (p=0.006). 28% patients with an abnormal caloric test had a normal vHIT, whereas 6% of those with an abnormal vHIT had a normal caloric test. The sensitivity of vHIT compared with caloric testing was 55% for MD and 40% for VM, neither the caloric test and vHIT could detect significant differences between early (<5 years) or advanced stages (>5 years) of MD or VM. (28)

In addition, it concluded that bithermal caloric test and the vHIT results were more abnormal in MD than in VM. hVOR evaluation with caloric test (low-frequency test) found more alterations than vHIT (high-frequency test). Therefore, both tests can be used in a complementary way for frequency-selective testing of peripheral vestibular function.

A research by Kitano et al. using inner ear magnetic resonance imaging (ieMRI) and vHIT, suggested that patients with MD could have EH significantly more often than those with non-MD. In cases with MD a positive EH sign on ieMRI did not always indicate a c-test/vHIT discrepancy; both findings may occur due to herniation of vestibular EH adjacent to the lateral semicircular canal. (29)

3.8 vHIT in pediatrics

In a prospective study by Kather et al. was found that the caloric test and vHIT are very important tests in diagnosis of dizzy patients. The information from both methods is redundant in some cases but complementary in most. vHIT is a "child friendly," relatively easy-to-use, and simple tool to evaluate each of the 6 semicircular canals. All studied cases, caloric test was normal. The mean age of patients was 16 years. By vHIT, in 8 patients (16%) no abnormality was detected, while abnormal findings were found in 41 patients (84%). (30)

Hamilton et al. in their study, the use of the vHIT in 33 patients <20 years old was retrospectively reviewed. Rotary chair testing was used to designate 26 subjects into groups with normal (n=20) and abnormal (n=6) lateral semicircular canal (LSC) function for comparison. LSC gain of <0.7 demonstrated sensitivity of 66.7%, specificity of 100%, positive predictive value of 100%, negative predictive value of 90.9% for detecting abnormal LSC function. Corrective saccades demonstrated 100% sensitivity and 100% specificity for detecting abnormal LSC function. Concluding that vHIT is a very effective test for evaluating semicircular canal function in children and offers major potential advantages over rotary chair and caloric testing. (31)

4.Discussion

In a comparative study between functional head impulse test (fHIT) vs vHIT. (3) Both the vHIT and fHIT exams correctly classified all patients as abnormal on the affected side when tested in the acute phase. After a 3-month follow-up, both studies were able to show a compensation phenomenon, otherwise the data from the two techniques were not correlated. More specifically the fHIT detected more abnormalities than the vHIT for head rotation toward the healthy side, both in the acute phase and after 3 months.

Blödow et al. found in his study, vHIT detects abnormal horizontal VOR changes in the combination of gain assessment and refixation saccades. Since isolated covert saccades in hVOR changes can only be seen with vHIT, peripheral vestibular disorders are likely to be diagnosed incorrectly with the clinical HIT in a certain amount. (32)

One study made by Halmagyi et al used vHIT (250 Hz) and search coils (1,000 Hz) simultaneously in 8 normal subjects, 6 patients with vestibular neuritis, 1 patient after unilateral intratympanic gentamicin, and 1 patient with bilateral gentamicin vestibulotoxicity. The vHIT is equivalent to search coils in identifying peripheral vestibular deficits but easier to use in clinics, even in patients with acute vestibular neuritis. (33) Check the table annexed to see the comparative gains found in different studies. (Table 1)

Test	Research Information	Disease	Gain
. Association of posterior semicircular canal hypofunction on video-head-impulse testing with other vestibulo-cochlear deficits	(Tarnutzer, 2017) Switzerland	Unilateral loss posterior semicircular canal	Posterior <0.7
Horizontal VOR function shows frequency dynamics in vestibular schwannoma.	(Blödow, 2015) Germany	Vestibular schwannoma	Lateral <0.79
The map of dizziness in vestibular schwannoma	(Batuecas-Caletrio, 2015) Spain	Vestibular schwannoma	Lateral <0.8
Caloric stimulation and video-head impulse testing in Ménière's disease and vestibular migraine	(Blödow et al., 2014) Germany	Meniere's disease Vestibular migraine	Main gain 0.60±0.11 Main gain 0.73±0.04
Video head impulse testing (VHIT) in the pediatric population.	(Hamilton, Zhou, & Brodsky, 2015)USA	Abnormal LSC function in children	Lateral <0.7
A new saccadic indicator of peripheral vestibular function based on the video head impulse test	(Macdougall et al., 2016) Australia	Bilateral vestibular loss	Lateral 0.29-0.36
Relación entre el video head impulse test (vHIT) y la prueba calórica en el estudio evolutivo de pacientes con neuritis vestibular.	(Redondo-Martínez et al., 2016) Spain	Vestibular Neuritis	Lateral 0.5
VOR Gain by Head Impulse Video-Oculography Differentiates Acute Vestibular Neuritis from Stroke	(Mantokoudis et al., 2015) USA	Vestibular Neuritis AICA PICA	Lateral 0.52 Lateral 0.79 Lateral 0.8

Table 1. Comparative table of studies using vHIT.

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5.Conclusions

After reviewing different research papers, we conclude that vHIT is a tool that allow us to effectively approach the diagnosis of diseases of the vestibular system, being compared with multiple studies, such as the caloric test, scleral search coil, fHIT and ieMRI. We found similar results comparing the caloric test against the search coils. fHIT detects more abnormalities than vHIT, but both techniques show a positive correlation with the Dizziness Handicap Inventory (DHI) Score.

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