

# Inversion Test and Sitting-Up Oculomotor Patterns in Patients with Gravitceptive Heavy Posterior Cupula – A Case Series

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## Abstract

A gravitceptive heavy posterior cupula typically results from cupulolithiasis and clinically manifests as short vertigo spells when the head moves in the provocative position. Half-Hallpike test (HHT) in posterior cupulolithiasis (PSC-BPPV-*cu*) elicits an upbeating ipsitorisional nystagmus (UBITN), which lasts more than a minute as per the consensus criteria developed by the Barany Society. In the last decade, cases with canalolithiasis in the short arm of the posterior semicircular canal (PSC-BPPV-*sa*), wherein the otoconial debris falls on the utricular side of the posterior cupula on getting up from supine, rendering it heavy (gravitceptive), have been reported. Such patients complain of sitting-up vertigo, associated with a constant disequilibrium, and anteroposterior truncal oscillations are recorded by *ad hoc* posturography in many of these patients. The oculomotor patterns generated in such patients during the HHT may be identical to those resulting from PSC-BPPV-*cu*. Rarely do the two conditions (PSC-BPPV-*cu* and PSC-BPPV-*sa*) coexist. Nine cases of gravitceptive heavy cupula were diagnosed at our center over a period of 6 months from September 1, 2022, to March 31, 2023, with their characteristic diagnostic oculomotor patterns, distinguishing features, and management discussed. We propose a grading system for the inversion test during the HHT that reliably distinguishes PSC-BPPV-*cu* from PSC-BPPV-*sa*, as well as when the two conditions coexist.

**Keywords:** Heavy cupula, posterior cupulolithiasis, short-arm posterior semicircular canalolithiasis

## INTRODUCTION

In 1969, Schuknecht dissected the temporal bones of two patients after their death who during their lives experienced short positional vertigo spells and found high specific-gravity basophilic deposits on the posterior cupula of the involved ear (which was undermost during the triggering of vertigo attacks).<sup>[1]</sup> A posterior cupula which is rendered heavy (gravitceptive) by the adherent otoconial debris, provokes paroxysms of vertigo whenever there is any head movement that bends the cupula, and the evoked positional nystagmus persists as long as the provocative head position is maintained.<sup>[2]</sup> The heavy gravitceptive posterior cupula is best evaluated by the half-Hallpike test (HHT), which is performed with the head rotated 45 degrees toward the side to be tested and resting slightly raised from supine (about 30 degrees in flexion).<sup>[2,3]</sup> HHT brings the heavy posterior cupula to an earth-horizontal position and deflects it maximally by the gravitational force generating an upbeating ipsitorisional positional nystagmus (UBITN) of more than a minute duration.<sup>[3]</sup> In recent years there have been reports of a heavy gravitceptive posterior cupula in patients of benign paroxysmal positional vertigo (BPPV) resulting from free-floating otoconial debris in the short arm of the posterior semicircular canal (PSC-BPPV-*sa*) that generates UBITN of more than a minute during the HHT, and the PSC-BPPV-*sa* often coexists with posterior cupulolithiasis (PSC-BPPV-*cu*) or long ampullary arm posterior semicircular canalolithiasis (PSC-BPPV-*laa*).<sup>[4,5]</sup>

From September 1, 2022, to March 31, 2023, our Otoneurology Centre in south Rajasthan evaluated nine patients with a history of positionally-triggered short vertigo spells who fulfilled the criteria<sup>[3]</sup> of PSC-BPPV-*cu*, with the diagnostic HHT eliciting prolonged duration (more than a minute) UBITN.

## MATERIALS AND METHODS

We undertook the following diagnostic positional tests in each of the patients:

**Dix-Hallpike Test (DHT):** is performed by moving the patient from a long-sitting to supine position with the head turned 45 degrees to one side so that the neck extends about 20 degrees at the free edge of the examination table with the tested ear down.

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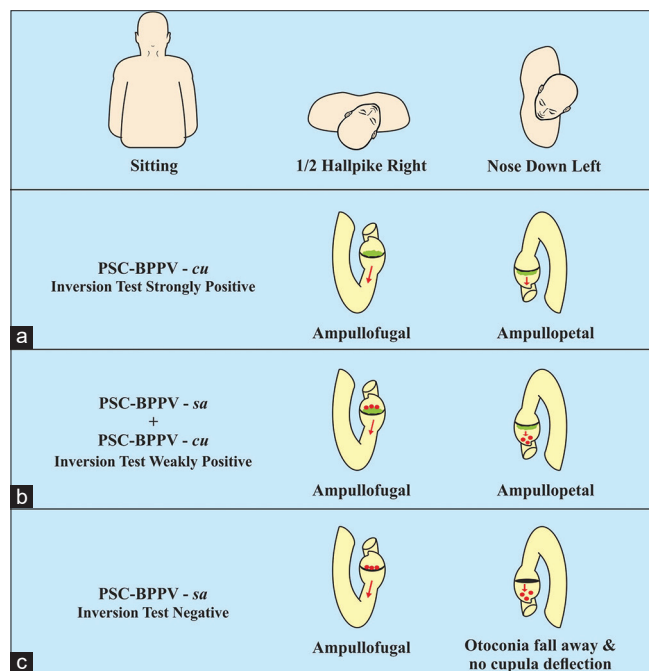
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**Oculomotor Patterns on Sitting-Up from DHT:** UBITN on sitting-up from DHT indicates PSC-BPPV-*sa* and were observed/recorded in all nine patients.

**HHT:** is conducted exactly as the DHT, but the 45-degree rotated head from upright long-sitting to supine is carried to just 60 degrees (instead of 120 degrees). A pillow of 4-inch thickness placed at the head end of the examination table suffices because a 45-degree rotated head lands on it and gets anteflexed about 30 degrees with resultant half-Hallpike positioning.

**Inversion Test:** If HHT elicits a UBITN of more than a minute duration, we position the patient contralateral recumbent with a nose down to observe the inversion of positional nystagmus from UBITN to downbeating contratorisional (DBCTN), which is a positive inversion test, indicative of an adherent type of cupulolithiasis.<sup>[2]</sup> We interpret a positive inversion test as strongly positive (++) if the inversion nystagmus is as intense as it is in the HHT (PSC-BPPV-*cu*), weakly positive (+) if it is less intense than in the HHT (PSC-BPPV-*cu* + PSC-BPPV-*sa*), and (-) negative it disappears (PSC-BPPV-*sa*) [Figure 1].

**Therapeutic Maneuvers:** Patients were treated with Epley maneuver (EM) for PSC-BPPV-*laa*,<sup>[6]</sup> Semont Maneuver (SM),<sup>[6]</sup> Mastoid Oscillation (MO),<sup>[7]</sup> Brandt-Daroff treatment (BDT)<sup>[8,9]</sup> for PSC-BPPV-*cu*, on day-1 and home-based BDT for four weeks for patients with PSC-BPPV-*cu* and/or PSC-BPPV-*sa*. Verifying positional tests to look for the elimination of positional nystagmus and accompanying vertigo were performed after 1 hour, at 24 hours, and at 4 weeks after the therapeutic maneuver and/or physical therapy.



**Figure 1:** Inversion test in PSC-BPPV-*cu*, PSC-BPPV-*sa*, and when two coexist

**Observations**

During 6 months, we examined and treated at our otoneurology center nine patients (three males and six females) who fulfilled the Barany Society<sup>[3]</sup> criteria of posterior semicircular cupulolithiasis (HHT eliciting UBITN of >60 seconds) [Table 1]. The inversion test was negative in three patients (patients 1, 3, and 7) who had sitting-up vertigo with a constant feeling of disequilibrium and elicited UBITN on getting up from the lateralized DHT. In one of these three individuals (patient 1), the UBITN during the head-hanging position of DHT was less than 60 seconds, suggesting the coexistence of PSC-BPPV-*sa* and PSC-BPPV-*laa*. For the remaining six patients, the results of the inversion test showed a change in the pattern of nystagmus from UBITN in HHT to DBCTN in the inversion position. In patients 6 and 8, we observed a significant attenuation of DBCTN in the inversion position compared to the robust prolonged duration UBITN seen in the HHT, suggesting that nonadherent particles significantly contributed to the graviceptive heavy posterior cupula, and our group interpreted this dampening of inversion nystagmus as weakly positive. In one of these patients (patient 8), there was UBITN with visibly significant anteroposterior truncal oscillations<sup>[10]</sup> on getting up from the left DHT, confirming the presence of PSC-BPPV-*sa*.

In summary, we found that two out of nine patients solitary had PSC-BPPV-*sa* (patients 3 and 7), four out of nine patients had exclusive PSC-BPPV-*cu* (patients 2, 4, 5, and 9), and of the remaining three, the PSC-BPPV-*sa* coexisted with PSC-BPPV-*cu* in 2 (patients 6, and 8), and with PSC-BPPV-*laa* in 1 (patient 1). We observed that none of the nine patients treated with MO, SM, and BDT responded to these physical therapies at short-term follow-ups of 1 hour and at 24 hours. However, on follow-up at 4 weeks with home-based BDT, all patients were asymptomatic with the resolution of oculomotor patterns and accompanying vertigo during the positional tests.

**DISCUSSION**

A heavy graviceptive posterior cupula typically results from otoconial debris adherent to it, but free-floating otoconial debris, if present in the short arm of the posterior semicircular canal, can fall on its utricular side during getting up from supine, rendering it heavy (graviceptive), and generate UBITN of >1-minute duration during the HHT. Each cupula has two potential provocative positions 180° oriented to each other. The earthward deflection in one position is stimulatory, and in another position, inhibitory. If the particles adhere to the cupula, persistent nystagmus will occur in both positions, in the same plane, but will reverse direction when they turn the head through 180°. Identification of this “*nystagmus reversal with head inversion*” confirms cupulolithiasis. If persistent nystagmus maximizes in one provocative position but does not occur in the inverse position, it suggests PSC-BPPV-*sa* because the nonadherent particles fall away from the utricular surface of the cupula to the short arm of the posterior semicircular canal in the inverse position. Accordingly, the inversion test is negative

**Table 1: Synopsis of patients – age, gender, duration, inversion, positional tests, diagnosis, physical therapy, and follow-up**

| Age and Sex | Symptom Duration | Dix-Hallpike Test (DHT) | Half-Hallpike Test (HHT) | Inversion Test | Oculomotor Patterns on sitting-up from Hallpike Test | YouTube Link  | Diagnosis  | Physical Therapy Given   | Follow-up at 1 h and 24 h                | Follow-up at 4 weeks |
|-------------|------------------|-------------------------|--------------------------|----------------|--|---|--|--|--|----------------------|
| 42/F        | 7 d              | Rt. UBITN <60s          | Rt. UBITN >60s (At 24 h) | -              | UBITN  | <a href="https://youtu.be/_Md3g68F6jA">https://youtu.be/_Md3g68F6jA</a> | Rt. PSC-BPPV- <i>laa</i> + Rt. PSC-BPPV- <i>sa</i> | EM on day-1 for Rt. Posterior Ampullary Arm Canalolithiasis; BDT for Rt. Short Arm Posterior Canalolithiasis | HHT + & UBITN on Sitting-Up from Rt. DHT | Asymptomatic         |
| 37/M        | 4 d              | Rt. UBITN >60s          | Rt. UBITN >60s           | ++             | None   | <a href="https://youtu.be/A2QDw0W7e7A">https://youtu.be/A2QDw0W7e7A</a> | Rt. PSC-BPPV- <i>cu</i>                            | MO, SM & BDT   | Symptomatic                              | Asymptomatic         |
| 43/F        | 6 d              | Negative                | Lt. UBITN >60s           | -              | UBITN  | <a href="https://youtu.be/MCB3rk5wbY4">https://youtu.be/MCB3rk5wbY4</a> | Lt. PSC-BPPV- <i>sa</i>                            | BDT  | Symptomatic                              | Asymptomatic         |
| 32/M        | 14 d             | Rt. UBITN >60s          | Rt. UBITN >60s           | ++             | None   | <a href="https://youtu.be/nq7R7egpic">https://youtu.be/nq7R7egpic</a>   | Rt. PSC-BPPV- <i>cu</i>                            | MO, SM & BDT   | Symptomatic                              | Asymptomatic         |
| 63/M        | 15 d             | Rt. UBITN >60s          | Rt. UBITN >60s           | ++             | None   | <a href="https://youtu.be/mFhH_xwjZjA">https://youtu.be/mFhH_xwjZjA</a> | Rt. PSC-BPPV- <i>cu</i>                            | MO, SM & BDT   | Symptomatic                              | Asymptomatic         |
| 60/F        | 4 d              | Rt. UBITN >60s          | Rt. UBITN >60s           | +              | UBITN  | <a href="https://youtu.be/xAjy2qkx90A">https://youtu.be/xAjy2qkx90A</a> | Rt. PSC-BPPV- <i>cu</i> + Rt. PSC-BPPV- <i>sa</i>  | MO, SM & BDT   | Symptomatic                              | Asymptomatic         |
| 52/F        | 8 d              | Negative                | Rt. UBITN >60s           | -              | UBITN  | <a href="https://youtu.be/UqHmxujidM8">https://youtu.be/UqHmxujidM8</a> | Rt. PSC-BPPV- <i>sa</i>                            | BDT  | Symptomatic                              | Asymptomatic         |
| 70/F        | 3 d              | Lt. UBITN >60s          | Lt. UBITN >60s           | +              | UBITN with anteroposterior truncal oscillations      | <a href="https://youtu.be/xKJawbM-foA">https://youtu.be/xKJawbM-foA</a> | Lt. PSC-BPPV- <i>cu</i> + PSC-BPPV- <i>sa</i>      | MO, SM & BDT   | Symptomatic                              | Asymptomatic         |
| 41/F        | 1 d              | Rt. UBITN >60s          | Rt. UBITN >60s           | ++             | None   | <a href="https://youtu.be/cYqw0Aqv2Y">https://youtu.be/cYqw0Aqv2Y</a>   | Rt. PSC-BPPV- <i>cu</i>                            | MO, SM & BDT   | Symptomatic                              | Asymptomatic         |

M=Male, F=Female, *d*=days, *s*=Seconds, Rt. & Lt.=Right & Left, UBITN=upbeating ipsitorional nystagmus, EM=Epley maneuver, MO=mastoid oscillation, BDT=Brandt-Daroff treatment, PSC-BPPV-*laa*=long ampullary arm posterior semicircular canalolithiasis, PSC-BPPV-*sa*=short-arm posterior semicircular canalolithiasis, PSC-BPPV-*cu*=posterior semicircular cupulolithiasis, ++=Stronger, +=Weaker, -=Absent

**Table 2: Common Terms and Definitions**

| Term                                      | Definition   |
|---|--|
| Short-arm of posterior semicircular canal | Short portion of posterior semicircular canal positioned just below the utricle when the patient is upright. <sup>[4,5]</sup>  |
| Heavy (graviceptive) posterior cupula     | Density of posterior cupula increases relative to that of endolymph resulting in ampullofugal deflection in the provocative position solely because of its own weight. Mostly results from posterior cupulolithiasis and rarely from short-arm posterior semicircular canalolithiasis. <sup>[12]</sup> |
| Posterior cupulolithiasis                 | Otoconial debris adherent to posterior cupula (either on the utricular or canal side), making it heavy. <sup>[11]</sup>  |
| Inversion test                            | A positive inversion test implies that UBITN in the HHT turns into DBCTN in the inversion position. <sup>[2,11]</sup><br>The authors of this case series have suggested grading of the inversion test – strongly positive (++), weakly positive (+), and negative (-) [Figure 1]                       |

in PSC-BPPV-*sa*, positive in PSC-BPPV-*cu*, and in the patient in which PSC-BPPV-*sa* coexists with PSC-BPPV-*cu*, the inversion nystagmus will dampen because of the partial *off-loading* of the posterior cupula by the nonadherent particles falling away from the utricular side to the short-arm, and our group interprets this as weakly positive (patient 6, and 8).

In a recent study<sup>[5]</sup> from the Southeastern Province of China, 48 out of 171 (about 40 percent) cases of PSC-BPPV were found to have concurrent PSC-BPPV-*sa*, who responded to a novel ‘bow-and-yaw’ maneuver that aided in distinguishing it from coexisting PSC-BPPV-*laa*. Our observations regarding the resolution of positional nystagmus and accompanying vertigo in 4 weeks in patients with PSC-BPPV-*cu* with and without PSC-BPPV-*sa* are in accordance with those of Ichiho<sup>[11]</sup> and Scocco.<sup>[4]</sup> In view of a small number of patients with a lack of control arm, we cannot decide whether this was due to the home-based BDT or the natural history of the disorder. We believe that the uncommon variant PSC-BPPV-*sa* may occasionally coexist with PSC-BPPV-*laa*. The latter may be unveiled as a cause of residual dizziness after successful treatment of PSC-BPPV-*laa* with the repositioning maneuvers (patient 1).

## CONCLUSION

The spectrum of PSC-BPPV-*sa* appears to vary from subjective vertigo through constant disequilibrium, positional, and sitting-up vertigo with and without oculomotor patterns of UBITN elicited on HHT, as well as on getting up from the lateralized DHT.<sup>[4,10]</sup> It is speculated that very small light weight otoconial particles in the short arm of the posterior semicircular canal remain floating and result in chronic mild posterior cupular deflection, especially in the upright position causing a constant disequilibrium without generating oculomotor patterns on positional tests. On the contrary, the heavier otoconial debris would result in significant ampullofugal posterior cupular deflection and lead to UBITN on HHT and on getting up from the lateralized DHT. It is, therefore, imperative to carry out DHT, HHT with inversion test and examination of oculomotor patterns on sitting-up from DHT in all patients suspected to be suffering from PSC-BPPV-*sa*. Because PSC-BPPV-*cu* and PSC-BPPV-*sa* both elicit UBITN of >1 minute duration during the HHT, it is crucial to perform an inversion test and to observe oculomotor patterns on sitting-up from DHT in all such patients to elucidate the etiology of the graviceptive heavy

posterior cupula [Figure 1]; whether resulting solitarily from an adherent type of posterior cupulolithiasis (PSC-BPPV-*cu*) or short-arm posterior semicircular canalolithiasis (PSC-BPPV-*sa*), as the two conditions (PSC-BPPV-*cu*, and PSC-BPPV-*sa*) may occasionally coexist (patients 6 and 8). We have defined a few terms in Table 2 as a ready reckoner for a better understanding of this arduous topic.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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## Conflicts of interest

There are no conflicts of interest.

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