Vertigo in whiplash injury: A presentation of prevalent butterfly patterns of caloric tests

Naik Chetana · Claussen C. F.

Abstract The most common cause of whiplash injury today is the road traffic accidents. These patients report to a neurotologist with complaints of long-standing duration including vertigo, nausea, hearing loss and tinnitus. In addition to neck trauma there is also intracranial trauma due to movement of the brain within the skull thus affecting the brainstem and the supratentorial structures. In this retrospective study 426 patients of whiplash injury were selected from databank NODEC IV of the University head centre, Würzburg, Germany. The results of monaural caloric test by means of butterfly chart in all these patients were analysed. The authors present the most prevalent caloric butterfly patterns of this study and pathophysiology explaining them. The study reveals that the more frequent pathological patterns in this study are the central brainstem lesions.

Keywords Butterfly chart · Caloric test · Central disinhibition · Vertigo · Whiplash injury

Introduction

‘Whiplash injury’ [1] occurs as a result of violent movement of the head with forceful extension and flexion of the neck, thereby resulting in injury to the cervical spine and the soft tissues. The most common cause of this kind of trauma today is the ‘rear end’ collision in road traffic accidents, as was first published by Gay and Abbott in 1953 [2].

These patients report to a neurotologist with long standing complaints like vertigo, instability, nausea, tinnitus and hearing loss in addition to neck pain and stiffness [3]. The mechanism of triggering vertigo from the neck is partly explained by work of Barre’ and Lieou. The trauma causes an over excitation of cervical proprioceptors resulting in hyper tonicity of gamma fibres and sympathetic nerves of the neck triggering thus the vertigo and vegetative symptoms [4]. However there is also intracranial trauma due to movement of brain within the skull thus affecting the brainstem and the supratentorial structures that can give rise to similar complaints.

Material and methods

In our study we selected 426 patients of whiplash injury resulting from head and neck trauma, from Claussen’s databank (NODEC IV), Würzburg University Head Centre, Germany. Amongst these we found that 47% of the patients had a history of road traffic accident, followed by those with falling accidents at work place (23%), at home (22%) and lastly a few with sports accidents (8%). All these patients underwent neurotological history taking by means of the form NODEC III. Some selected subjective complaints with percentage of their occurrences are listed in Table 1.

Table 1 shows that statistically 2.02 of the six vertigo symptoms occurred per patient of this group of whiplash injury. Two hundred and twenty-nine (53.76 %) patients complained of hearing loss and 243 (57.04 %) of tinnitus.

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Table 1 Selected neurotological complaints with percentage of their occurrences in 426 patients of head and neck trauma with whiplash injury (426 = 100%).

Complaint	Percentage of occurrence
Vertigo symptoms	
Rocking	45.07
Lifting	8.45
Rotatory	51.41
Falling	26.53
Blackout	25.59
Instability	45.07
Ear complaints	
Tinnitus	57.04
Hearing loss	53.76

All the patients were subjected to electronystagmography (ENG) with Claussen's monaural calorisation test [5, 6]. In 399 out of 426 subjects (93.66%) the history of trauma had been more than a year before the investigations of ENG, caloric tests and audiometry were performed. Most of them (44.37%) had chronic symptoms of vertigo, 9.39% had symptoms lasting for decades. In 13 cases (3.05%) the trauma had occurred few months ago, in 3 patients a few weeks earlier and in only one patient 10 days before the ENG was done.

With the patient in supine position with 30° head elevation, the ear canals were irrigated with 20 ml of water over 30 sec starting with right warm (44°C) followed by left warm, then right cold (30°C) and then finally left ear cold and the nystagmus was recorded with a 5-channel ENG. The nystagmus beats in the 30 sec culmination phase were counted and then represented on the Claussen's butterfly chart along with the trinary code [6]. The response is coded as '0' for normal, '1' for response below normal and '2' for above normal for each of the tests. The trinary code is then represented in 4 digits in the order of right warm, right cold, left warm and left cold.

Observations

We then ranked the different caloric butterfly patterns according to the occurrence rates in descending order. The 11 most prevalent of these are shown in the following Table 2.

From Table 1 it is clear that, about one third of the patients had a normal butterfly pattern (0000), but two third of them had an abnormal pattern. The ten prevalent patterns after the normal butterfly comprise 37.38%, which is also around a third of the sample.

Amongst the abnormal frequency butterfly patterns the

Table 2 Occurrence rates of the 11 most prevalent caloric butterfly charts in 426 patients of whiplash injury.

Sr. no	Trinary Code	Percentage of occurrence
1	0000	33.5
2	0022	4.9
3	2222	4.9
4	0002	4.64
5	2000	4.12
6	0010	3.87
7	0020	3.35
8	0200	3.35
9	1000	3.09
10	0100	2.58
11	0001	2.58

most common were the 0022 and the 2222. They indicate a monolateral or bilateral central vestibular lesion resulting in disinhibition of the vestibular nuclei. The other frequent patterns indicated partial central disinhibitory states i.e. the trinary codes 0002, 2000, 0020 and 0200. The warm caloric inhibitory responses of the type 1000 and 0010 were seen, demonstrating a typical peripheral vestibular functional loss like after a labyrinthine concussion or traumatic vascular cause [7]. We also see quite a few cases of peripheral cold inhibitory type namely the trinary codes 0100 and 0001.

We now present a clinical example for each of the Claussen's caloric frequency butterfly patterns related to the trinary codes presented in Table 2. CODE 0000 Figure 1.

This is a patient aged 40 who had a falling accident at his workplace. Despite his subjective symptoms of vertigo and diplopia, his calorigram shows a normal trinary code of 0000. CODE 0022 Figure 2.

Amongst the abnormal patterns the trinary code of highest occurrence was 0022. This is a typical asymmetric major butterfly pattern of a 49-year-old female patient showing normal right side responses and overactive left responses. The patient had vertigo, instability, bilateral hearing loss and tinnitus, years after a road traffic accident. The monolateral over activity is found if the inhibitory bundles from the nucleus fastigii of cerebellum of one side to the vestibular nuclei of opposite side are disturbed at the level of the corpus juxtarestiforme. The healthy side (left) shows an over activity as the contralateral inhibitory influence from the right is lost. Such a pattern is found in whiplash injuries of the cervico-encephalic type. CODE 2222 Figure 3.

This chart depicts a typical 'Major Butterfly' wherein the overactive responses are seen on both sides. The 35-year-old male patient presented with spinning vertigo, tinnitus and

Fig. 1 CODE 0000

Fig. 3 CODE 2222

Fig. 2 CODE 0022

hearing loss. This is a bilateral cerebello-pontine nystagmus disinhibition (trinary code 2222) as a result of a brainstem lesion. This again belongs to a typical cervico-encephalic whiplash syndrome. CODE 0002 Figure 4.

Fig. 4 CODE 0002

This young patient with vertigo complains of right-sided tinnitus and hearing loss following whiplash injury. His caloric frequency butterfly chart however shows normal responses on the right but only an overactive cold response

on the left. i.e. the trinary code 0002. This indicates an incomplete pontomedullary lesion on right. CODE 2000 Figure 5.

Fig. 5 CODE 2000

This caloric butterfly chart of patient with home accident shows an overactive right warm response indicating again an incomplete disturbance at brainstem level on the left. He also has tinnitus and hearing loss on the left side. CODE 0010 Figure 6.

The butterfly chart of this 44-year-old patient, who suffered from head and neck trauma 13 years ago, shows left warm inhibition indicating a left peripheral receptor loss. The falling tendency to the right could be due to an over compensation. CODE 0020 Figure 7.

This patient of road traffic accident with vertigo, tinnitus and right hearing loss has disinhibited left warm response showing a partial disinhibition induced from the right side of the brainstem. CODE 0200 Figure 8.

This butterfly chart shows an overactive or disinhibited right cold response with trinary code 0200. This partial disinhibition points towards a left brainstem lesion. CODE 1000 Figure 9.

This caloric butterfly shows inhibition of the right warm response, indicating a right peripheral receptor lesion. The patient had forehead trauma with whiplash injury and complained of spinning vertigo. CODE 0100 Figure 10.

In this patient of neck trauma years ago complaining of instability the cold caloric response on the right is inhibited

Fig. 6 CODE 0010

Fig. 7 CODE 0020

while the other responses are normal. This demonstrates an irritative lateral canal receptor on the right and not a hypoactive labyrinth. CODE 0001 Figure 11.

Fig. 8 CODE 0200

Fig. 10 CODE 0100

Fig. 9 CODE 1000

Fig. 11 CODE 0001

This chart shows an inhibited left cold caloric response in an adult male with whiplash trauma complaining of vertigo and tinnitus. It indicates a left irritative labyrinth.

Two hundred and twenty-nine (53.76 %) patients complained of hearing loss and 243 (57.04 %) of tinnitus. All the 426 patients were subjected to pure tone audiometry.

Sensorineural hearing loss in midfrequencies (500 and 2K) was found in right ear in 25 (5.87%) cases, in the left ear in 35 (8.22%) cases and in both ears in 18 (4.23%) cases. Sensorineural hearing loss at 250 Hz and 4K was seen in right ear in 29 (6.8%), in left ear in 44 (10.33%) and in both ears in 38 (8.92%) subjects. In all 44.37% of the 426 patients were objectively found to have sensorineural hearing loss. Only 10.15% had conductive deafness.

Hearing loss (2.9%) and tinnitus (2%) were seen even in those one – third of our cases who had normal butterfly pattern on ENG. Amongst the first ten of the most prevalent patterns of butterfly calorigrams the evidence of hearing loss was analyzed. Twenty-five percent of the subjects having central disinhibitory patterns on caloric tests (suggesting central vestibular lesions) had hearing loss and tinnitus. This can be explained by central cause for deafness due to vascular or nerve trauma during the head and neck injury.

Amongst the subjects whose ENG suggested peripheral vestibular lesions, 50.5% had confirmed hearing loss. Labyrinthine concussion resulting from inner ear trauma affecting the vestibule as well as cochlea at the time of head trauma explains the findings

Discussion and conclusions

Injury to the head and neck is one of the common causes of vertigo and dizziness, nowadays. The whiplash injury has become a modern civilisation disease. Its increasing frequency is closely related to the growing numbers of cars in our modern times. The term “common whiplash injury” has become popularized in relation to traffic accidents due to a publication of Gay and Abbott in 1953 [2].

By the use of seat belts, the amount of direct wounds is reduced in modern motor vehicles. However the energy impact upon the person, sitting in a car which is struck by another car, is absorbed in the head and neck through an abrupt hyperextension and hyperflexion movement, which also is called the whiplash injury mechanism. The severity of the post-traumatic symptoms depends on the site of the cervical lesions and the extent of the damage to the spine, the soft tissues of the neck, the cervical blood vessels and also the trauma to the brain. Four types of post-traumatic whiplash syndromes can be differentiated [4]:

- Cervical syndrome
- Cervicobrachial syndrome
- Cervicomedullary syndrome
- Cervicoencephalic syndrome.

Cervical syndrome is a condition caused by irritation or compression of the cervical nerve roots, marked by pain in the neck radiating into the shoulder, arm, or forearm, depending on which nerve root is affected. In daily practice these are of interest to the orthopedic surgeons.

The cases with chronic complaints of dizziness, hearing

loss, tinnitus, instability also summarized under the term “late whiplash injury syndrome”, nowadays play the most important role in the neurotological everyday practice. Mostly these cases belong to group “cervico-encaphalic syndrome”. Also they are the ones termed as minor head injuries by the medical experts, who have seen the patients earlier. Tinnitus, hearing loss and vertigo can appear separately or together; suddenly or as the worsening of chronic complaints. The causes of vertigo, deafness and tinnitus can appear as central or peripheral lesions.

Our study of the 426 patients of head and neck trauma of whiplash type exhibits that on an average a patient of this group presents with 2.02 of the specific vertigo symptoms. The history is a subjective, psychophysical investigative procedure since the days of the Czech investigator Purkinje (autognostic principle). The ENG was invented by Schott [8] in 1922. Dix and Hallpike described the bithermal calorisation test [9]. This was later modified by Claussen by using a well defined scheme for calorisation using the water temperatures of 30°C for cold and 44°C for warm, but with lesser quantities (20 ml) and time for irrigation of 30 sec. Claussen’s results were evaluated by frequency of nystagmus beats during the culmination period which then were transferred to the Claussen caloric butterfly chart. Eighty-one different patterns of butterfly could be differentiated. For this study we have selected 426 cases from the databank NODEC IV containing 10,335 cases totally. With respect to the post-traumatic vertigo due to whiplash mechanisms, the monaural caloric vestibulo-ocular test by butterfly chart could detect 33% of the cases as normal and 67% as pathological.

The most frequent types of the 10 pathological butterflies show that the majority of the pathologies are related to brainstem dysfunctions like major and minor brainstem disinhibitions.

The GABA-ergic fibres from the purkinje cells of the cerebellum passing via the inferior peduncle cross to opposite side in the brainstem (ponto medullary junction) and exert an inhibitory effect on the vestibular nucleus of opposite side. A brainstem lesion at the level of the corpus juxtaestiforme on ipsilateral side will, disinhibit the vestibular nucleus on the contralateral side thus showing a hyperactive response on caloric test for the contralateral side. If both sides are involved we get a major butterfly (code-2222), unilateral involvement will show butterfly code 0022 or 2200 and partial disinhibitions may be seen like 0200, 0020 etc.

Besides, however, all the four patterns of peripheral vestibular pathology at the receptor level are seen in this sample. Two patterns exhibit distal receptor degenerations (1000 and 0010). Animal experiments performed by Barany [10] have shown how a peripheral receptor loss expresses itself in the calorisation results of nystagmus inhibition.

The irritative states of the inner ear hair cells were postulated since the work of Meniere. Here it should

be noted that in the area of nystagmus regulator in the brainstem, the information coming from the right and left vestibular receptors are compared. Normally a monolateral cold stimulus induces a decrease in the firing rate at the ipsilateral canal receptor, whereas the non-stimulated opposite receptor remains at its resting level activity. A surplus of data arising on the non-stimulated side results in a cold nystagmus beating towards the non-stimulated ear.

However, in an irritated receptor with an elevated basic firing rate, the stimulus may not be enough to lower the firing rate sufficiently below that of the non-stimulated opposite side. Then the balance of data comparison is too small for triggering a significant cold nystagmus, resulting in a cold inhibition pattern. So the two phenomena of peripheral vestibular receptor inhibition must be evaluated and seen in a completely different manner.

All in all, the more frequent pathological patterns in our study are the central brainstem lesions. It must also be mentioned that one third of our cases showed normal patterns, so they could not be positively evaluated by the caloric nystagmus test alone.

So it can be concluded that two-third of the head and neck cases with whiplash are open for an analysis by using tests for vestibulo-ocular nystagmus reflexes. Yet the rest one-third needs other investigations like the vestibulo-spinal tests including the Cranio Corpora Graphy (CCG).

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