Alternobaric Vertigo—a Diving Hazard

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Brit. med. J., 1965, **2**, 511–513

It is well known that the change in external pressure is one of the major factors in diving accidents. The mechanisms by which this creates such conditions as depth narcosis, rupture of the lung, and decompression sickness are either known or under investigation. Nevertheless, many accidents cannot be explained in terms of classical diving hazards.

This paper concerns a reaction to pressure change that has hitherto been largely overlooked as a potential cause of such accidents. Although reports were published as early as 1896 by Alt and in 1909 by Keays of vertigo occurring at the end of exposure to increased pressure environment, there are few accounts of this subject in the literature on labyrinthine function or on diving medicine. Fields (1958) reports four cases of brief vertigo in connexion with surfacing after dives, and Coles and Knight (1961) recorded three cases in connexion with Navy divers' clearing their ears. Rowe (1961) also mentions that vertigo may occur in divers, and reports one case without discussing the specific cause.

Personal experience of sudden rotational vertigo during the ascent from diving, as well as in the hyperbaric chamber, induced the present study.

Methods

A questionary was sent to 550 members of the Swedish Association of Sport Divers (see Appendix). In the introduction it was emphasized that all information they provided was to be treated in strict confidence on a patient–doctor basis, and also that no attempt would be made to interfere with anyone's personal diving habits.

The questionary was designed to elucidate the frequency of the vertigo, the conditions under which it might occur, the possibility that it might interfere with the diver's performance, etc. In an additional inquiry 15 of the subjects who had had vertigo (including some of the most serious cases) were asked for their experiences of vertigo on land.

Results

Answers to the inquiry on vertigo were listed as positive only if such factors as caloric stimulation, breathing impure air, depth narcosis, decompression sickness, seasickness, sensory deprivation (Rawlins, 1960 ; Miles, 1962), food-poisoning, and overdistension of the gut by air could be definitely excluded or were most unlikely to have caused the sensation. Exertion, hypoxia, and hyperventilation were also in some instances thought to be the cause of vertigo. The answers of 26 subjects who had experienced vertigo were classified as negative for the reasons mentioned above.

Of the 354 subjects who answered, 92 (26%) had experienced vertigo during Scuba (self-contained underwater breathing apparatus) diving or when diving by breath-holding. There is no difference in age distribution between those who had had vertigo and those who had not. Some of the conditions under which the phenomenon occurred are summarized in the Table.

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The questionary included a question whether the subjects were able to produce vertigo by blowing with the nose clamped and so forcing air into the ears. In a few cases personally observed by me this manœuvre produced, immediately upon application of the pressure, severe vertigo combined with horizontal nystagmus, nausea, and loss of balance. In one case the subject (subject A—see below) was thrown headlong to the floor. Some subjects made the observation that vertigo may be preceded or followed by a clicking sound or—during the Valsalva manœuvre—by the hissing of air entering the middle-ear cavity. One subject described his experience on a certain occasion in the following words: " . . . intense nausea. As I reached the surface it was whirling around madly. I panicked but managed to grasp my friend's clothes, which calmed me down . . . then at last there was a click in my head and the surface at once stopped whirling. . . ." Another subject (Subject A—see above) reports that he might have intense vertigo even when getting ashore after the dive. In such cases he gets rapid relief when he descends again or uses nose-drops. This diver, who is very experienced, estimates that he is troubled by vertigo in about 20% of his dives unless he uses nasal decongestants before diving, in which case the vertigo may be prevented.

Several divers pointed out that they have more trouble with vertigo when for some reason, such as a recent cold, pressure equilibration has been more difficult than usual, or that it appears only after a series of dives carried out during the same day. Once when suffering from a nasal catarrh I developed an attack closely resembling Ménière's syndrome when I forced air into the ears to relieve a sensation of fullness which had persisted for some time. The picture included horizontal rotational vertigo, which forced me to lie down, nystagmus (probably to the left) making fixed vision impossible for a minute or two, a loud buzzing sound in the left ear, and

Summary of Some Details

Question No.	Answer	No. of Subjects	% of Vertigo Group
6	Vertigo every dive or often ..	5	5
	Occasionally	86	95
11	Vertigo with Scuba	73	80
	Without	9	10
	With and without	9	10
7	Vertigo on ascent or surfacing	67	73
	On descent or bottom	19	21
	On ascent and descent	4	4
12	Vertigo very or rather troublesome	17	18
	Scarcely or not troublesome ..	69	75
	Orientation difficult under water	10	11
	Difficult to swim, climb into boat, walk	5	5
	Nausea (vomiting—one case) ..	10	11
9	Vertigo on Valsalva*	25	27
	" " " *	10/53	% of non-vertigo group—19
4	Difficulty in clearing ear on one side†	28	30
	" " "	50	% of non-vertigo group—19

Discrepancies between the number of subjects and the number of answers are due to the failure of some subjects to answer certain questions.

* Owing to a technical imperfection, the question of vertigo and the Valsalva manœuvre was observed by only 53 of those who had never had vertigo when diving. No significant difference in the reaction to the Valsalva manœuvre was found between those who had and those who had not experienced vertigo when diving.

† There was an almost significant association ($0{\cdot}05 > P > 0{\cdot}01$) between experience of vertigo when diving and unilaterally dominant difficulties in pressure equilibration.

pronounced reduction in hearing on the same side. All the symptoms disappeared completely after five minutes. It is noteworthy that I have always had the greatest difficulty in obtaining pressure equilibrium in my left ear, and that the attack started at the same moment as air was heard to enter on that side.

Spontaneous descriptions illustrate the difficulties that vertigo may cause in diving. Thus the duration of the vertigo is said to vary from a few seconds to 15 minutes. One of the major complaints of divers who have had vertigo is the difficulty of finding the way to the surface. In some instances this was severe enough to cause the subject to swim towards the bottom when he intended to ascend. One diver describes another situation: "I started the ascent. When I was only about one metre above the bottom vertigo started and increased, finally becoming unbearable when I was only a few metres up. I got immediate relief on returning to the bottom. Two more attempts to ascend ended in the same way. Finally, I got hold of my friend's waist and was pulled to the surface. During the ascent the vertigo was very intense, I had no idea of what was up and what was down—it was impossible to fix any objects visually. When we reached the near-by shore the vertigo rapidly vanished." Another diver reports that he floated up, thanks to positive buoyancy, though owing to vertigo he was not sure he was up even when he broke the surface. In one case double vision is reported, whereas others have seen the bottom or surface take on an unusual angle, turn over slowly several times, or rotate rapidly. One diver heard a buzzing sound together with the vertigo. A number of subjects spontaneously reported that vertigo usually appeared in the latter part of the ascent and that the intensity of the sensation varied with the rate of the ascent. The diving depth did not seem to be important, as vertigo had occurred in dives to depths of 2 to 30 metres or more.

Of the 15 subjects who had had vertigo when diving and were asked for similar experiences on land, all denied these except for occasions when some of them had been able to produce vertigo by blowing air into the middle ears and two or three reports of occasional normal orthostatic reactions.

Discussion

The few reports on disturbed labyrinthine function during diving and caisson work usually blame the abnormal pressure milieu. Nevertheless, the suggestions made as to the mediating mechanisms vary. Thus Fields (1958) mentions that the sensation disappeared shortly after surfacing, and postulates that the cause was "nothing more than unusual displacement of the stapes in the oval window giving temporary vertiginous symptoms." Melvill Jones (1957) thought that "pressure vertigo" among fliers might be due to eddy currents over the utricular and saccular maculae and the ampullary cupulae. These may be induced by sudden movements of the stapes during pressure equilibration in the middle ears. It is difficult, however, to connect the briefness of the stimulation, which he stresses, with the duration of the vertigo, which in some divers in this investigation lasted up to 15 minutes. Rowe (1961) lists a number of possible origins of vertigo and for no clear reason considers that caloric stimulation is the most important of them. In a case reported by Filippin (1963) an underwater swimmer developed severe vertigo and disorientation as he reached 5 metres' depth after having swum down slowly. Otological examination revealed intense hyperaemia and a lesion in the patient's right eardrum—that is, signs of classical barotrauma. In reports on Ménière-like conditions among caisson workers and deep-sea divers, it is usually suggested that the often-protracted illness arises from bleeding in the labyrinths, due to incomplete pressure equilibration, or that too rapid decompression causes bubble formation in the semicircular canals (Alt, 1896); Heller *et al.*, 1900; Keays, 1909; Vail, 1929).

In the present investigation none of these mechanisms seemed to explain disturbed labyrinthine function during diving. Differences in pressure between the middle-ear cavity and the surrounding structures were of paramount importance in the development of diver's vertigo. As most subjects had vertigo on the way to or upon reaching the surface it seems that a relative overpressure in the middle ear is an important factor. This is in keeping with Melvill Jones's (1957) findings in aviators. These conclusions are in large measure supported by two observations made by several subjects: firstly, that stopping the ascent, and preferably descending again, rapidly alleviated the vertigo; secondly, that the subjects could produce vertigo on dry land by forcing air into the middle ears by blowing against the clamped nose. Nevertheless, as it was impossible to verify that the divers performed the Valsalva manœuvre correctly, some of them might have evoked false vertigo (Coles and Knight, 1961) by maintaining a prolonged intrathoracic overpressure that produced gross circulatory disturbances.

Obviously other conditions, apart from abnormal pressure in the middle ears, must exist as well if vertigo is to appear. Thus asymmetry in the pressure fluctuations of the two ears may have an important role. Of the divers who had vertigo 30% reported that when they encounter difficulties in pressure equilibration these are usually unilaterally dominant, whereas only 19% of those who had no vertigo report such asymmetry —an almost significant association ($0.05>P>0.01$). Furthermore, some divers have noted the hissing of air on one side together with the appearance or disappearance of vertigo. Most workers state that vertigo and nystagmus should not develop in normal persons subjected to pressurization by insufflation. If great pressures (more than 100 mm. Hg) are applied it may sometimes be possible to evoke a pseudofistula symptom (Karlefors-Nylén), but such pressures are unlikely to develop in connexion with the ascent from diving.

Another possibility that must be considered is that a chronic physical abnormality could predispose to vertigo. But this cannot be of the kind that could be detected at a routine otological examination, as the majority (83%) of the subjects who had vertigo state that they had passed a special medical examination for diving. Another finding is that the development of vertigo seems to be independent of the subject's experience of diving.

Obviously, serious vertigo is a grave menace to the diver. Vomiting while under water would generally be fatal, while disorientation for even a short time would be hazardous, especially if the air supply is exhausted or if the diver is not carrying a breathing apparatus. In fatal cases there is unlikely to be any direct evidence of vertigo, though it should be suspected in the not infrequent case when a drowned diver is found to be wearing a still-functioning Scuba.

As to the frequency of vertigo among divers, Coles and Knight (1961) found it to agree closely (3 divers out of 30) with Melvill Jones's (1957) observations on fliers (19 out of about 200 pilots). But if the potential intensity of the stimulus (rate and magnitude of the pressure change) is directly related to vertigo, it would be expected to be much more common among divers, as I have found. One factor which might influence the results in surveys of this kind (especially when conducted by doctors in the Services) is the tendency for divers and pilots to minimize their experiences or to attribute them to external causes rather than to physiological upsets. In the introduction to the questionary used in this investigation precaution was taken to avoid this source of error.

Thus vertigo is sufficiently common among divers, and potentially severe enough, to deserve a wider recognition, particularly by workers in the field of diving medicine. In addition, I would suggest that it should be known as "alternobaric vertigo (vertigo alternobarica)."

From the point of view of prognosis alternobaric vertigo itself seems to be essentially benign. However, because of its potentially deleterious effects all possible steps should be taken to avoid it—for example, diving should not be undertaken when the person has a cold, nor preferably immediately after a cold when it is more difficult than usual to clear the ears. The correct use of nasal decongestants is also recommended in cases where pressure equilibration is difficult despite the absence of recent infection. Great care should be taken always to keep pressure equilibration timed with external pressure change and to avoid unnecessarily rapid ascents and descents. Intermittent swallowing during ascent, though not necessary for pressure equilibration, may possibly facilitate it, thus further reducing the risk. Divers who are inclined to vertiginous reactions of the type described should avoid pressure exposures which make the use of stage decompression necessary.

The author would like to acknowledge the valuable criticism and discussion of the manuscript offered by Surgeon Captain S. Miles and Surgeon Lieutenant-Commander R. R. A. Coles, R.N.

Summary

The occurrence of vertigo in connexion with external pressure variations has been studied among sport divers by means of a questionary.

The phenomenon, which is here called "alternobaric vertigo," appears from this investigation to be a serious potential menace to divers.

Some aetiological mechanisms and preventive or therapeutic measures which might prove important are discussed.

Appendix. Questionary

1. I *have/have not* undergone medical examination in connexion with diving. Date.....

2. The result *was/was not* satisfactory, owing to .....

3. In connexion with diving I have *always/often/seldom/never* had difficulties with pressure equilibration.

4. In case of difficulties with pressure equilibration I have *more/equal* difficulties with the *right (and) left* ear(s). I *usually/never/also/only* have difficulties with the *nasal sinuses/cheeks/forehead.*

5. To obtain pressure equilibration I usually *open the mouth* (move the jaw)*/swallow/blow against the clamped nose/do nothing special.*

6. When I dive I *always/often/occasionally/seldom/never* experience vertigo (a whirling sensation).

7. The vertigo usually appears *at the surface* (upon ascent)*/during ascent/during descent/at the bottom.* The greatest depth reached in dives in which vertigo was experienced was .....metres. (Not necessarily the same as the depth at which the vertigo appeared.)

8. The visibility in the water when the vertigo appeared was .....metres.

9. When I had vertigo I had *not/possibly/for certain* a ruptured *right/left* eardrum. I *wore/did not wear* a hood. I *can/cannot* induce vertigo by forced blowing against the clamped nose.

10. I *believe/do not believe* that the vertigo was due to seasickness. It *may/cannot* have been caused by breathing *impure air/food-poisoning/or* .....

11. When I had vertigo I *never/sometimes/always* wore breathing apparatus.

12. The vertigo I had was *very/rather/scarcely/not at all* troublesome. Mention if possible how many times you have had vertigo and how troublesome it was (e.g., difficulty in finding the way to the surface, swimming ashore, etc.) .....

13. When I dive I *always/often/occasionally/seldom/never* have nausea. The nausea is then *always/sometimes/never* connected with the vertigo mentioned above.

[A number of questions treating nausea as an entity separate from the vertigo were then put. The results will be presented in a separate publication.]

14. If you have had vertigo, mention how long it persisted and what you did to eliminate it .....

15. Additional information .....

[In an additional inquiry 15 of the subjects who had had vertigo (including some of the most serious cases) were asked for their experiences of vertigo on land.]

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Estimations of Blood Volume During Course of Renal Failure

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Brit. med. J., 1965, **2**, 513–516

Oliguric renal failure may be associated with a considerable dislocation of the normal partitioning of the body fluids, but relatively few studies of such changes have been made in man. We have performed serial estimations of blood volume in 50 patients with oliguric renal failure. Observations were made throughout the course of the disease, and the effects of haemodialysis and of peritoneal dialysis have been observed. This paper outlines some of the results, which have provided information on the fluid shifts occurring as a result of renal failure, and have also on occasion materially assisted in the management of these patients.

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Method and Materials

An automatic isotope dilution technique was employed, using a machine, the Volemetron, which can be set for iodinated serum albumin, or chromated red cells, or both (Williams and Fine, 1961). Because of its greater simplicity, we have used iodinated