Tzu Chi Medical Journal 23 (2011) 46–50

Contents lists available at ScienceDirect

Tzu Chi Medical Journal

journal homepage: www.tzuchimedjnl.com

Original Article

Use of sodium bicarbonate for acute dizziness after minor head injury

Yuan-Chia Cheng, Wei-Che Lee, Liang-Chi Kuo, Yen-Ko Lin, Chao-Wen Chen, Tsung-Ying Lin, Hsing-Lin Lin*

Division of Trauma, Department of Surgery and Emergency Medicine, Kaohsiung Medical University Hospital and Kaohsiung Medical University, Kaohsiung, Taiwan

ARTICLE INFO

Article history:
Received 1 April 2011
Received in revised form
25 April 2011
Accepted 9 May 2011

Keywords:
Dizziness
Minor head injury
Normal saline
Sodium bicarbonate
Visual analog scale

ABSTRACT

Objective: Dizziness after minor head injury (mHI) is common. In some eastern countries, it is treated with 7% sodium bicarbonate solution (SB). This prospective study evaluated the clinical efficacy of SB compared with normal saline (NS).

Material and methods: From April 2009 to April 2010, we performed a prospective observational study on 228 patients (68% female, 32% male) with acute dizziness after mHI. At the emergency physician's discretion, intravenous SB (1 mL/kg) in NS (250 mL) or NS (250 mL) was administered to 166 patients and 62 patients, respectively, as empiric antidizziness therapy. Outcome measures were severity of dizziness and treatment response, which were measured by a visual analog scale. Various characteristics were compared between treatment groups. Any continued dizziness of the patients during follow-up was also compared with their pre-injury condition, such as prior psychiatric disorders and the presence of vertigo.

Results: The SB group had their visual analog scale scores reduced by 25.4% compared with 24.6% in the NS group. Both groups showed a statistically significant reduction in dizziness ($p < 0.001$); however, the dizziness improvement did not differ significantly between the two treatment groups ($p = 0.699$). Sixty-four patients (28.1%) suffered from continued dizziness during follow-up (mean period, 22.4 ± 28.9 days). The prevalence of continued dizziness was higher in patients with prior psychiatric disorders, although this was not statistically significant (40% *vs.* 27.2%, $p = 0.276$), whereas patients with prior vertigo did not experience a higher dizziness relapse rate (27% *vs.* 28.2%).

Conclusions: SB and NS administrations are both effective individually when treating patients with acute dizziness from mHI; however, both results may be attributable to the placebo effect. Therefore more research is necessary to understand the complex conditions that determine the effects of SB on this disorder.

1. Introduction

Dizziness has been shown to be the most prominent symptom of discomfort after minor head injury (mHI) and affects 74% of patients within the first few days. The patients also suffer vague symptoms of disorientation, and light-headedness as well as more concrete symptoms such as illusions of movement and imbalance. These can be accompanied by autonomic symptoms such as nausea or vomiting. All these symptoms give rise to inconvenience during daily life activities. Nevertheless, most symptoms are mitigated within 2 weeks [1]. Dizziness is thought to occur when neurological motor functions and sensory balance fail to work together, peripheral sensory modalities of the vestibular and auditory systems are damaged, proprioceptors over the neck are injured, or as a result of posttraumatic stress disorder [2,3].

Intravenous administrations of 7% sodium bicarbonate solution (SB) had been used to treat Meniere patients in the past without any negative effects [4–9]. The effect of SB on vertigo and dizziness is attributed to a reduction of lymph hydrops in the semicircular canals of the inner ear or degradation of blood sludge in peripheral capillaries in the labyrinth, thereby inhibiting the neural activity of the medial vestibular nucleus [4,5,8,9]. Chiu et al, who studied low-dose SB (1 mL/kg) administration in animals and in a clinical trial, demonstrated a 62% success rate for SB treatment of dizziness induced by the peripheral vestibule organ [10,11]. Hence, SB administration was claimed to be effective without significant complications in alleviating troublesome autonomic symptoms during acute vertiginous attack. Based on these studies, some

Conflict of interest: none.

* Corresponding author. Division of Trauma, Department of Surgery and Emergency Medicine, Kaohsiung Medical University Hospital, 100 Tzyou 1st Road, Kaohsiung, Taiwan. Tel.: +886 73121101x7579; fax: +886 73208255.
E-mail address: hsinglin2002@yahoo.com.tw (H.-L. Lin).

1016-3190/$ – see front matter
doi:10.1016/j.tcmj.2011.05.002

physicians in Japan and Taiwan use SB as an empiric therapy in an Emergency Department (ED) setting for patients who have sustained concussion and have dizziness; however, its clinical effectiveness has not been well established.

Normal saline (NS) is a typical pharmacological placebo, meaning that no evidence exists in the literature of its specific activity for the condition being treated. Nevertheless, several studies have demonstrated the significant psychological effects of placebos on continuous subjective outcomes and pain treatment [12,13]. Furthermore, some of our emergency physicians prefer using NS to treat patients with subjective feelings of dizziness. Here, we evaluate and compare the efficacy of SB and NS for the treatment of acute dizziness after mHI at an ED.

2. Materials and methods

2.1. Patients and setting

This is a prospective observational study with chart review. This study was approved by the Institutional Human Investigations Committee and the Institutional Review Board of Kaohsiung Medical University Hospital. This 1200-bed university hospital is located in the center of a city and provides medical services for the local population. Patients who received intravenous antidizziness agents for acute dizziness after mHI were enrolled. Patients were excluded if intracranial lesions were found on computed tomography (CT), if their outcome information was incomplete after record review, or if they received any other antidizziness medication during treatment. All received standard care at the ED in accordance with the Advanced Trauma Life Support guidelines published by the American College of Surgeons. A standardized form of trauma sheet is used for every trauma patient and this includes personal information, trauma mechanisms, physical examinations, clinical management with laboratory data and tests, and diagnoses at the ED. All patients were asked to return to our outpatient clinic for follow-up within 7 days of discharge as a part of the protocol for ED discharge.

2.2. Data collection

All clinical data, including age, gender, medications, diagnosis on hospital admission, patient history, body weight, initial systolic blood pressure and body temperature, injury cause, history of post-injury vomiting and headache, and time from injury to treatment, were retrieved from the trauma registration data set of our data bank and the individual's medical records by an emergency physician. All brain CT scans in the ED and the ultimate length of hospital stay were also reviewed. All patients' charts were reviewed for a period of 4 months to identify any episodes of continued dizziness.

The duration of posttraumatic amnesia and presence of transient loss of consciousness were estimated according to the information from patients or witnesses. We defined mHI as a blunt blow to the head resulting in posttraumatic amnesia <1 hour, initial loss of consciousness <15 minutes, a Glasgow coma scale (GCS) score of 14–15 on ED presentation, and absence of focal neurological signs with no intracranial lesions on brain CT [14,15]. Patients with intracranial lesions were excluded because of the need for additional medical therapies and possible difficulty in obtaining correct dizziness tests. Continued dizziness was defined as documented dizziness in the outpatient clinic; dizziness duration was calculated from the injury date to the date of follow-up at which no complaints were voiced or to the date of a failure to revisit.

The mechanisms of the patients' traumas were classified into four subgroups: (1) motor vehicle accident-related (i.e., road vehicle collisions), (2) assault-related (i.e., head trauma caused by violence, including domestic violence), (3) fall-related (i.e., injuries caused by head impact after falling), and (4) head bump related (i.e., any other type of impact-related head trauma). All identifying personal characteristics were removed from the original database before analysis.

2.3. Procedures

Patients with acute dizziness after mHI who received intravenous antidizziness agents at the ED were included in this study. Eligible patients were administered empiric antidizziness treatment with either intravenous SB or NS at the physician's discretion. Before antidizziness treatment, the patients were evaluated for their level of dizziness using a visual analog scale (VAS) and they graded their dizziness sensation from 1 (least severe) to 5 (most severe). The standardized protocol in our ED to treat dizziness patients was administration of either SB (1 mL/kg dose) in 250 mL of NS or 250 mL of NS alone, both by slow intravenous infusion (5 mL/min). A second VAS was used to measure patients' dizziness level scores at 1 hour post-treatment. Gender, age, past history, Glasgow coma scale score, mHI cause, and presence of headache with or without vomiting were recorded at first examination. Traumatic injuries to limbs, trunk, or head were also recorded in the trauma sheet. Any radiological examination report was also obtained. No alternative forms of antidizziness therapy were used to treat these enrolled patients. If dizziness did not improve after treatment, the patient was assigned bed rest for several hours in the ED. Brain CT scans were considered to rule out intracranial lesions. Furthermore, the patients were considered for hospital admission and further observation. At discharge, patients were routinely asked to visit our outpatient clinic for follow-up.

2.4. Statistical analysis

Demographic and medical data were compared and statistically analyzed between the two treatment groups. Data were reported using percentages, means, medians, and standard deviations, depending on the type of variable. Categorical variables were analyzed using χ^2 analysis. The difference in VAS scores between the SB and NS groups were analyzed by repeated-measures analysis of variance. Pearson correlation was used to calculate the relation between continuous variables. A p value <0.05 was considered statistically significant. All statistical operations were performed using SPSS 14.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results

Two hundred and fifty-six patients who came to our ED between April 2009 and April 2010 with acute dizziness after mHI and who received intravenous antidizziness agents were enrolled in this study. Fig. 1 shows the disposition of the 256 potential eligible mHI patients in our study. Twenty-eight patients (10.9%) were excluded from analysis because 7 (2.7%) patients showed anatomic lesions on brain CT, whereas outcome information for the other 21 (8.2%) patients was incomplete. Ultimately, 228 patients were included in our analyses. Of the patients, 155 (68%) were women, and 73 (32%) were men (mean age, 36.79 ± 17.66 years). Eligible patients were divided into two groups according to treatment with intravenous SB ($n = 166$) or NS ($n = 62$). A comparison of characteristics and demographics showed no significant differences between the two treatment groups in terms of age, gender, times from injury to treatment, hemodynamics, trauma mechanism, length of hospital stay, and prevalence of continued dizziness during follow-up except for the incidence of posttraumatic

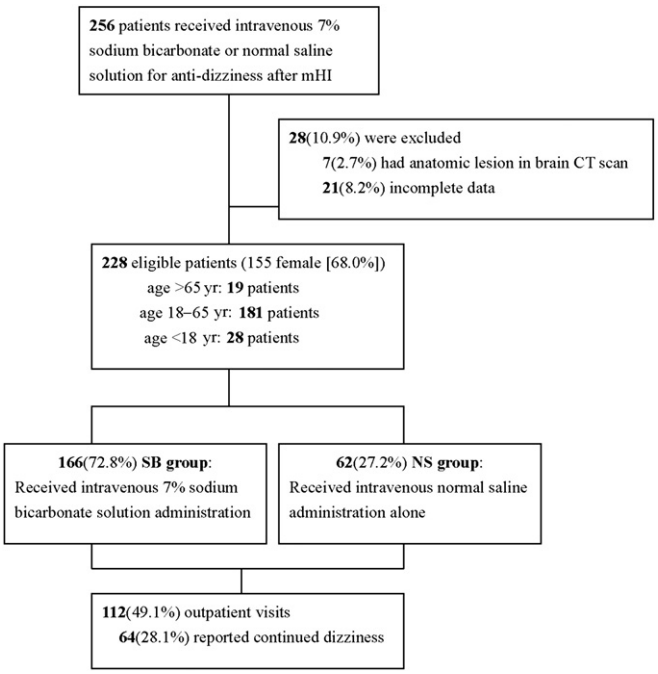

Fig. 1. Disposition of the overall study population.

vomiting (15.7% in the SB group *vs.* 37.1% in the NS group; $p < 0.001$; Table 1).

The overall mean VAS scores pretreatment and posttreatment were 3.00 ± 0.87 and 1.74 ± 0.79, respectively. Thus there was a 1.27-point reduction in the mean VAS score in the SB group and a 1.23-point reduction in the NS group. Both reductions were significant (25.4% and 24.6% reduction, respectively; $p < 0.001$). However, the VAS improvement was not significantly higher in the SB group than in the NS group ($p = 0.699$). The study population was further divided into subgroups to identify factors affecting the outcome measure, but no significant differences among the subgroups related to brain CT implementation, gender, age, or cause of head trauma were found (p value >0.05 for all) (Table 2), indicating that the symptoms of all subgroups of patients who received either NS or SB improved equally after treatment.

Most blunt head injuries in our study resulted from motor vehicle accidents, assaults, head bumps, and falls. Motor vehicle accident was the leading cause of head trauma in the study population (58.8%). Dizziness was found predominantly in women (68%), whereas men suffering dizziness were younger than women (31.86 ± 18.02 *vs.* 39.11 ± 17.06, $p = 0.04$). However, both sexes experienced a significant improvement in symptoms post-treatment, with no significant difference between the genders. The average length of hospital stay was 10.4 ± 21 hours. Overall, 28% of subjects experienced continued dizziness during follow-up, and the mean period of continued dizziness was 22.4 ± 28.9 days. Continued dizziness in patients with prior psychiatric problems, such as anxiety and depression, was not significantly higher than that in patients without problems (40% [6 of 15] *vs.* 27.2% [58 of 213] patients, respectively; $p = 0.276$). Patients with prior vertigo did not have a significantly higher relapse of dizziness during follow-up than non-vertigo patients (27% [4 of 15] *vs.* 28.2% [60 of 213], respectively). No adverse systemic effects were noted in our cases, but a small number of patients felt soreness at the injection site, which was relieved with a warm compress.

4. Discussion

The main finding of our study is that administering of either SB or NS is an efficacious treatment of alleviating dizziness related to mHI. The SB group had their VAS scores reduced by 25.4% compared with 24.6% for the NS group; however there was no statistically significant difference between the two groups.

Table 1
Baseline characteristics of the enrolled study population

Characteristics	SB group ($n = 166$)	NS group ($n = 62$)	p
Age, mean ± SD (yr)	35.38 ± 17.11	40.56 ± 18.69	0.059[b]
Female, No. (%)	116 (69.9%)	39 (62.9%)	0.315[a]
Time to treatment, mean ± SD (hr)	34.55 ± 94.57	34.74 ± 72.55	0.714[b]
Hospital LOS, mean ± SD (hr)	9.96 ± 17.01	11.47 ± 29.37	0.631[b]
Posttraumatic vomiting, No. (%)	26 (15.7%)	23 (37.1%)	<0.001[a]
Posttraumatic headache, No. (%)	71 (42.8%)	23 (37.1%)	0.439[a]
Brain CT scan, No. (%)	64 (38.6%)	28 (45.2%)	0.366[a]
Systolic blood pressure, mean ± SD (mmHg)	137.62 ± 22.2	140.34 ± 24.17	0.423[b]
Body temperature, mean ± SD (°C)	37.05 ± 3	36.91 ± 0.44	0.726[b]
Body weight, mean ± SD (kg)	61.41 ± 14.38	61.18 ± 10.86	0.907[b]
Patient history			
Depression/anxiety, No. (%)	12 (7.2%)	3 (4.8%)	0.588[a]
Vertigo, No. (%)	11 (6.6%)	4 (6.5%)	0.829[a]
Cause of head trauma			
MVA-related, No. (%)	103 (62.0%)	31 (50%)	0.097[a]
Assault-related, No. (%)	14 (8.4%)	11 (17.7%)	
Fall-related, No. (%)	24 (14.5%)	13 (21%)	
Head bump related, No. (%)	25 (15.1%)	7 (11.3%)	
Continued dizziness			
No. of patients (%)	46 (71.9%)	18 (28.1%)	0.843[a]
Days, mean ± SD	25.24 ± 31.61	15.28 ± 19.14	0.217[b]

CT = computed tomography; LOS = length of stay; MVA = motor vehicle accident; No. = number; NS = normal saline (0.9%); SB = 7% sodium bicarbonate solution (1 mL/kg); SD = standard deviation.
[a] χ^2 analysis.
[b] Student's t test.

Table 2
Average patients' self-reported scores for the VAS of dizziness

	VAS score pretreatment	VAS score posttreatment	p[a]
Total ($n = 228$)	3.00 ± 0.87	1.74 ± 0.79*	
1. SB group vs. NS group			
SB group ($n = 166$)	3.00 ± 0.85	1.73 ± 0.78*	0.699
NS group ($n = 62$)	3.00 ± 0.86	1.77 ± 0.79*	
2. Implementation of brain CT			
Yes ($n = 92$)	2.95 ± 0.81	1.65 ± 0.67*	0.409
No ($n = 136$)	3.08 ± 0.94	1.87 ± 0.92*	
3. Gender			
Man ($n = 73$)	3.08 ± 0.85	1.79 ± 0.80*	0.377
Woman ($n = 155$)	2.84 ± 0.88	1.64 ± 0.75*	
4. Age			
<18 yr/o ($n = 28$)	2.71 ± 0.789	1.37 ± 0.60*	0.747
18–65 yr/o ($n = 181$)	3.07 ± 0.89	1.82 ± 0.82*	
>65 yr/o ($n = 19$)	2.88 ± 0.60	1.71 ± 0.59*	
5. Cause of head injury			
MVA-related ($n = 134$)	3.13 ± 0.86	1.89 ± 0.87*	0.733
Assault-related ($n = 25$)	2.72 ± 0.74	1.56 ± 0.51*	
Fall-related ($n = 37$)	2.89 ± 0.94	1.51 ± 0.65*	
Head bump-related ($n = 32$)	2.78 ± 0.83	1.53 ± 0.57*	

Result reported as mean ± standard deviation.
*A p value ≤0.001 versus VAS score pretreatment by Student's t test.
CT = computed tomography; MVA = motor vehicle accident; NS = normal saline; SB = sodium bicarbonate; VAS = visual analog scale; yr/o = years old.
[a] Statistical differences among subgroups by repeated-measures analysis of variance.

Although clinical experience suggests a benefit from the use of solutions containing SB against dizziness in diseases that affect the vestibular system, such as Meniere's disease (in which dizziness is a major symptom), data on the effectiveness of such treatments remain limited [4–6,8–11,16]. In our study, the clinical response to SB was compared with responses in patients treated with NS of similar volume. We also rated the severity of subjective complaints and treatment response using a VAS. Both therapies were efficacious in treating dizziness related to mHI (Table 2, $p < 0.001$).

Dizziness is a common problem faced by busy emergency physicians. Previous studies have reported that mHI accounts for 90% of head injuries, whereas in the Taiwanese literature, 83%–87% head injuries have been classified as mildly severe [17–19]. Incidences of posttraumatic headache and dizziness have been reported to be as high as 90% at 1 month of post incident and approximately 25% at 1 year of post incident or more. Once established for more than a few weeks, symptoms often persist for months and tend to resist treatment, although they eventually lessen [20]. In our patients, 28.1% (64 of 228) had persistent symptoms on follow-up at our outpatient clinic, on average for 22.4 ± 28.9 days.

Dizziness may result from an emotional response, or it can be a symptom of injury or disease. In previous studies, women were more prone to have posttraumatic dizziness than men and it was found that a history of previous psychiatric disorder is a significant risk factor for postconcussion syndrome [21,22]. In our study, more women had dizziness than men after mHI; however, a history of psychiatric disorder or vertigo was not found to be a risk factor for continued dizziness. In an overview of postconcussion syndrome, King noted that both biological and psychological factors affect posttraumatic dizziness, and that patients tend to transform posttraumatic stress disorder into physical problems [23]. Nevertheless, differences in culture between the East and West may account for many of these differences. Most people in Asian countries are reluctant to consult psychologists because they think that it is a shame on the entire family if even one family member is diagnosed with a psychological disease. Therefore, individuals with psychiatric disorders might have been underestimated.

Although intravenous SB administration is thought to affect blood gas tests, Kawabata et al reported that the mean arterial blood PaO_2 was not significantly altered after using SB even after the serum bicarbonate ion level did increase dose-dependently and concomitantly with an increased pH after injection of the drug at doses of 1 mL/kg, 2 mL/kg, and 4 mL/kg. They also reported that the $PaCO_2$ did not significantly change after injection of the drug up to 2 mL/kg but that it temporarily increased after 4 mL/kg [5]. Hence, we concluded that the 1-mL/kg dose used in our study would not affect blood gas tests.

We chose NS in a volume of 250 mL as either a dilution of SB or empiric antidizziness therapy for the following reasons. First, SB is hypertonic and frequently causes irritation when administered intravenously. Because the drug may cause soft tissue damage if it extravasates, we routinely dilute SB in 250 mL of NS to reduce the incidence of local adverse effects. Second, 250 mL is the smallest volume package of NS available in our ED. Diluting to a lower SB dose (1 mL/kg) in a larger NS volume may prolong the time of the drug drip and resulted in insufficient pharmacotherapeutic effects. Third, a larger volume of fluid administration produces higher urinary frequency and more changes in position when going to the toilet might exacerbate the feeling of dizziness. It is therefore appropriate to use a smaller volume of fluid under these conditions.

Although patients responded to the administration of both SB and NS in our study, we are aware that during its natural course dizziness after mHI might either increase or decrease. Patients often see doctors when their complaints peak. Fluctuating subjective feelings may be relatively high on admission and lower at the end of treatment, and this might be quite unrelated to the effects of the therapy or any placebo effect. It is possible that patients, after asking for symptom ratings post-treatment, become sensitized to the problem under evaluation, and either deliberately or unconsciously, attempt to affect the clinical outcome. Although using SB for dizziness has been proved in many studies, no difference in improvement in the dizziness ratings was observed in our study between the SB and NS groups (Table 2, $p = 0.699$). This implies that the effect of SB may simply be a placebo effect and similar to the assumed placebo effect of NS. We also divided patients into several subgroups to explore other factors that might have affected outcome (Table 2), but no significant differences were observed among these subgroups, and all patients improved regardless of treatment type.

In this study, dizziness lessened under different therapeutic options following a short period of bed rest after injury, which suggests that bed rest may have some palliative effect. However, in a randomized clinical trial of 107 people, bed rest was demonstrated to be ineffective as a means of speeding up recovery in patients with postconcussion syndrome [24]. In our study, dizziness in 58 patients (25.4%) was not reduced more than 24 hours after injury pretreatment, and 5 patients (8.6%) experienced dizziness for more than 2 weeks after/of post-treatment. Therefore, a short period of bed rest in the ED was not the cause of dizziness improvement.

This study had several limitations. Our results represent the experience of a single institution and may reflect the characteristics only of local patients. Thus, selection bias may have occurred. However, our treatment groups were well matched and had similar demographic and clinical characteristics. We did not compare outcomes with an observation-only group and therefore the placebo effect was not explicitly examined in this study. We investigated patients who sought help at the ED only. Many people with dizziness following mHI may not seek medical advice or they might visit another facility initially or at follow-up; therefore, the prevalence of dizziness may have been underestimated. The absence of a follow-up record does not necessarily mean that nonreturning patients were free of dizziness. Therefore, we cannot determine the frequency or natural history of this disorder. The response to SB or NS may be related to patient bias, patient expectations, and to our enrollment of patients with relatively mild symptoms of head trauma. Thus it is difficult to distinguish between reporting bias and the placebo effect on the subjective outcomes. Patients may report improvement when none has occurred to please the physician.

5. Conclusion

Acute dizziness after mHI may result from various complex interactions among anatomical and neuropsychological processes as well as cognitive–behavioral and environmental factors. The present study found that both SB and NS were efficacious in reducing dizziness. However, the natural disease course, the patients' expectations about treatment, and other nonspecific effects might all account for the positive response. More research with the inclusion of an untreated control group in placebo-controlled trials should be undertaken to better understand the complex conditions that may determine the therapeutic effect of SB.

Acknowledgments

We thank Ching-Ying Wu for statistical consultation in data analysis. The first and second authors had equal contributions. We are grateful to the participants and research staff.

References

[1] Yang CC, Tu YK, Hua MS, Huang SJ. The association between the post-concussion symptoms and clinical outcomes for patients with mild traumatic brain injury. J Trauma 2007;62:657–63.

[2] Maskell F, Chiarelli P, Isles R. Dizziness after traumatic brain injury: overview and measurement in the clinical setting. Brain Inj 2006;20:293–305.

[3] Hoffer ME, Balough BJ, Gottshall KR. Posttraumatic balance disorders. Int Tinnitus J 2007;13:69–72.

[4] Noriaki T. Drug therapy for vertigo. Clinic All-round 2006;55:2519–20.

[5] Kawabata A, Kishimoto T, Ujihara H, Sasa M, Takaori S. Inhibition by intravenously administered sodium bicarbonate of neuronal activity in medial vestibular nucleus neurons. Jpn J Pharmacol 1990;54:383–9.

[6] Celestino D, Cerulli N, Iannetti G, Sagliaschi G. Acid-base equilibrium in Meniere's disease. J Laryngol Otol 1976;90:263–75.

[7] Yazawa Y, Kitano H, Suzuki M, Tanaka H, Kitajima K. Studies of cochlear blood flow in guinea pigs with endolymphatic hydrops. ORL J Otorhinolaryngol Relat Spec 1998;60:4–11.

[8] Furstner J. Effects of sodium bicarbonate therapy in Meniere's disease, especially on dizziness. Orv Hetil 1956;97:185–8.

[9] Hasegawa T. The treatment of Meniere's disease by intravenous injections of a concentrated solution of sodium bicarbonate. Rev Laryngol Otol Rhinol (Bord) 1960;81:617–26.

[10] Chiu SY, Young YH. Sodium bicarbonate in the treatment of acute vertiginous attack – basic and clinical studies. J Taiwan Otolaryngol Head Neck Surg 1993; 28:133–8.

[11] Chiu SY, Young YH. Sodium bicarbonate for the therapeutic diagnosis of acute vertiginous attack. J Taiwan Otolaryngol Head Neck Surg 1995;30: 418–22.

[12] Katz J, Finnerup NB, Dworkin RH. Clinical trial outcome in neuropathic pain: relationship to study characteristics. Neurology 2008;70:263–72.

[13] McDonald CJ. Is the placebo powerless? N Engl J Med 2001;345:1276–7 [author reply 8–9].

[14] Stiell IG, Clement CM, Rowe BH, Schull MJ, Brison R, Cass D, et al. Comparison of the Canadian CT Head Rule and the New Orleans Criteria in patients with minor head injury. JAMA 2005;294:1511–8.

[15] Smits M, Dippel DW, de Haan GG, Dekker HM, Vos PE, Kool DR, et al. External validation of the Canadian CT Head Rule and the New Orleans Criteria for CT scanning in patients with minor head injury. JAMA 2005; 294:1519–25.

[16] Carson J, Tator C, Johnston K, Kissick J, Purcell L, Hunt B. New guidelines for concussion management. Can Fam Physician 2006;52:756–7.

[17] Wu X, Hu J, Zhuo L, Fu C, Hui G, Wang Y, et al. Epidemiology of traumatic brain injury in eastern China, 2004: a prospective large case study. J Trauma 2008; 64:1313–9.

[18] Chiu WT, Huang SJ, Tsai SH, Lin JW, Tsai MD, Lin TJ, et al. The impact of time, legislation, and geography on the epidemiology of traumatic brain injury. J Clin Neurosci 2007;14:930–5.

[19] Thornhill S, Teasdale GM, Murray GD, McEwen J, Roy CW, Penny KI. Disability in young people and adults one year after head injury: prospective cohort study. BMJ 2000;320:1631–5.

[20] Roe C, Sveen U, Alvsaker K, Bautz-Holter E. Post-concussion symptoms after mild traumatic brain injury: influence of demographic factors and injury severity in a 1-year cohort study. Disabil Rehabil 2009;31: 1235–43.

[21] Sigurdardottir S, Andelic N, Roe C, Jerstad T, Schanke AK. Post-concussion symptoms after traumatic brain injury at 3 and 12 months post-injury: a prospective study. Brain Inj 2009;23:489–97.

[22] Bazarian JJ, Wong T, Harris M, Leahey N, Mookerjee S, Dombovy M. Epidemiology and predictors of post-concussive syndrome after minor head injury in an emergency population. Brain Inj 1999;13:173–89.

[23] King NS. Post-concussion syndrome: clarity amid the controversy? Br J Psychiatry 2003;183:276–8.

[24] de Kruijk JR, Leffers P, Meerhoff S, Rutten J, Twijnstra A. Effectiveness of bed rest after mild traumatic brain injury: a randomised trial of no versus six days of bed rest. J Neurol Neurosurg Psychiatry 2002;73:167–72.