American Journal of Case Reports

e-ISSN 1941-5923
© Am J Case Rep, 2018; 19: 935-940
DOI: 10.12659/AJCR.909695

Received: 2018.02.28
Accepted: 2018.05.25
Published: 2018.08.10

Restoration of Balance and Unilateral Hearing Using Alternating and Filtering Auditory Training in Shunt-Treated Hydrocephalus Following Subarachnoid Hemorrhage: A Case Report

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

E Nico Milantoni
E Natale Di Bella
E Kariné Chahbazian

Department of Neurology, Neurorehabilitation Unit, South Paris University Hospital, Le Kremlin Bicêtre, France

Corresponding Author: Nico Milantoni, e-mail: nicomilantoni@gmail.com
Conflict of interest: None declared

Patient: Female, 54
Final Diagnosis: Ruptured aneurysm in the anterior communicating artery and hydrocephalus
Symptoms: Hemi-hyposthenia • proprioceptive left-sided ataxia • temporospatial disorientation • memory disorder • hearing loss
Medication: Nicardipine
Clinical Procedure: Shunting and neurorehabilitation program
Specialty: Neurology

Objective: Unusual or unexpected effect of treatment

Background: Although rehabilitation for balance disorders is commonly undertaken following a stroke, hearing dysfunction is rarely investigated, even though hearing loss affects the ability to maintain balance. This report presents a case of restoration of balance and unilateral hearing using an alternating and filtering auditory training (AFAT) protocol in a patient with subarachnoid hemorrhage (SAH) and shunt-treated hydrocephalus.

Case Report: A 54-year-old woman with a five-month history of SAH due to a ruptured aneurysm in the anterior communicating artery and hydrocephalus treated with a shunt was admitted to our unit for neurorehabilitation. The patient had a history of anorexia. Her initial neurological examination on admission for rehabilitation therapy showed postural instability, hemi-hyposthenia, proprioceptive left-sided ataxia, a confusional state including temporospatial disorientation, memory disorder and hearing loss. Two weeks after the start of her neurorehabilitation program the AFAT program was commenced. Pure tone audiometry (PTA) showed lower left hearing thresholds, extending from a hearing level (HL) of between 5–25 decibel (dB) or more when compared with the right ear. With a rapid and improved regain of unilateral hearing loss, balance, cognitive, and motor function also improved.

Conclusions: This case report supports that patients who undergo rehabilitation following stroke, SAH, and hydrocephalus might benefit from a rehabilitation program that includes hearing assessment and early improvement of hearing loss, leading to a shorter rehabilitation time.

MeSH Keywords: Hydrocephalus • Music Therapy • Physical and Rehabilitation Medicine

Full-text PDF: https://www.amjcaserep.com/abstract/index/idArt/909695

Indexed in: [PMC] [PubMed] [Emerging Sources Citation Index (ESCI)] [Web of Science by Clarivate]

Background

Vestibular, proprioceptive, and visual systems provide sensory information required to maintain static and dynamic balance, all of which can be affected in stroke patients [1]. The role of the evaluation of hearing in this context has not yet been well determined even though previous studies have highlighted the association between deficits in hearing and the incidence of falls, postural instability, and reduced mobility [2].

Although sensorineural hearing loss (SNHL) is not traditionally considered to be a feature of hydrocephalus, there is growing evidence supporting the link between altered cerebrospinal fluid (CSF) dynamics and hearing dysfunction [3]. Regular musical activities have shown to efficiently enhance the structure and function of many brain areas, making music a potential tool in neurological rehabilitation [4]. In this field, music-supported therapy has been shown to be an effective approach in the recovery of chronic motor dysfunction in patients with stroke [5]. A further supportive study for the role of improved hearing showed that the use of constraint-induced sound therapy was shown to be a suitable approach for recovery of unilateral SNHL [6].

This report presents a case of restoration of balance and unilateral hearing using an alternating and filtering auditory training (AFAT) protocol in a patient with subarachnoid hemorrhage (SAH) and shunt-treated hydrocephalus, who experienced good recovery.

Case Report

Clinical presentation

A 54-year-old woman was admitted to our unit to commence a neurorehabilitation program. The patient had a five-month history of disabling effects following a subarachnoid hemorrhage (SAH), which had been caused by a ruptured aneurysm of the anterior communicating artery, involving the interhemispheric anterior frontal area and the Sylvian fissure. The patient also presented with the effects of hydrocephalus following SAH and stroke. Following treatment with the implantation of a ventriculoperitoneal shunt, these effects lasted for approximately one-and-a-half months.

On hospital admission, neurological examination showed postural instability, hemi-hyposthenia, hemi-hypoesthesia, proprioceptive ataxia to the left side, a confusional state including temporospatial disorientation and memory disorder. At the time of her hospital admission, the patient was dependent on assistance with going to the toilet, dressing, and mobility.

Table 1. Physiotherapy assessments on the day of hospital admission showing physical function and the Held and Pierrot-Desseilligny scale scores.

Physical functions	On the day of admission
Ability to transfer	Can move with the help of one person
Ability to turn over	Can turn with the help of one person
Balance while sitting	Can remain seated with imbalance
Balance while standing (bipodal)	Can stand with the help of two persons
Balance while standing (unipodal)	Cannot stand
Walking	Can walk with the help of two persons
Held and Pierrot-Desseilligny score	**On the day of hospital admission**
Upper limbs	2/5
Lower limbs	3/5

Assessments of neurological function performed at the start of neurorehabilitation

On hospital admission, evaluation of her physical function was performed including the Held and Pierrot-Desseilligny scale, which showed a generalized motor deficit (Table 1). The Functional Independence Measure (FIM), Berg Balance Scale (BBS), and Mini-Mental State Examination (MMSE) scores were 35/126, 6/56, and 6/30, respectively. In addition to pharmacologic treatment, including venlafaxine and nicardipine, the patient followed a neurorehabilitation program consisting of physiotherapy and occupational therapy. Two weeks after the beginning of the standard neurorehabilitation program, due to the persistence of catatonia, neuro-cognitive and motor deficits, a decision was made to add an alternating and filtering auditory training (AFAT) protocol.

The alternating and filtering auditory training (AFAT) protocol, including pure-tone audiometry (PTA)

In compliance with the zero ISO 389-8: 2004 (F) [7,8], pure-tone audiometry (PTA) showed lower left hearing thresholds, extending from 5 to 25-decibel hearing level (dB-HL) or more, compared with the right ear (Figure 1). The average hearing gap between the two ears was ≥15.30 dB-HL. Following PTA, the patient received the AFAT treatment for 20 consecutive days, one session per day, for 30 minutes a day.

Indexed in: [PMC] [PubMed] [Emerging Sources Citation Index (ESCI)] [Web of Science by Clarivate]

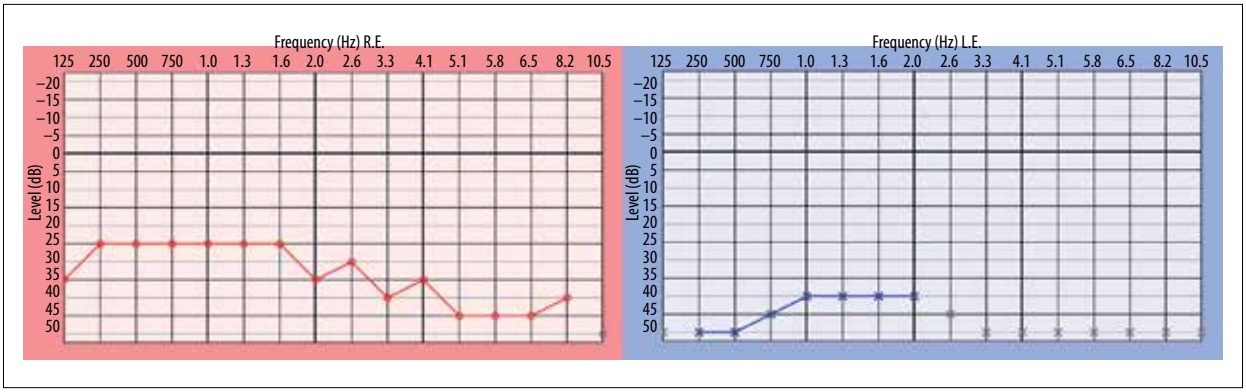

Figure 1. Audiogram findings, before the use of the alternating and filtering auditory training (AFAT) program. The average hearing gap is ≥15.30 decibel (dB) hearing level (HL) between the two ears.

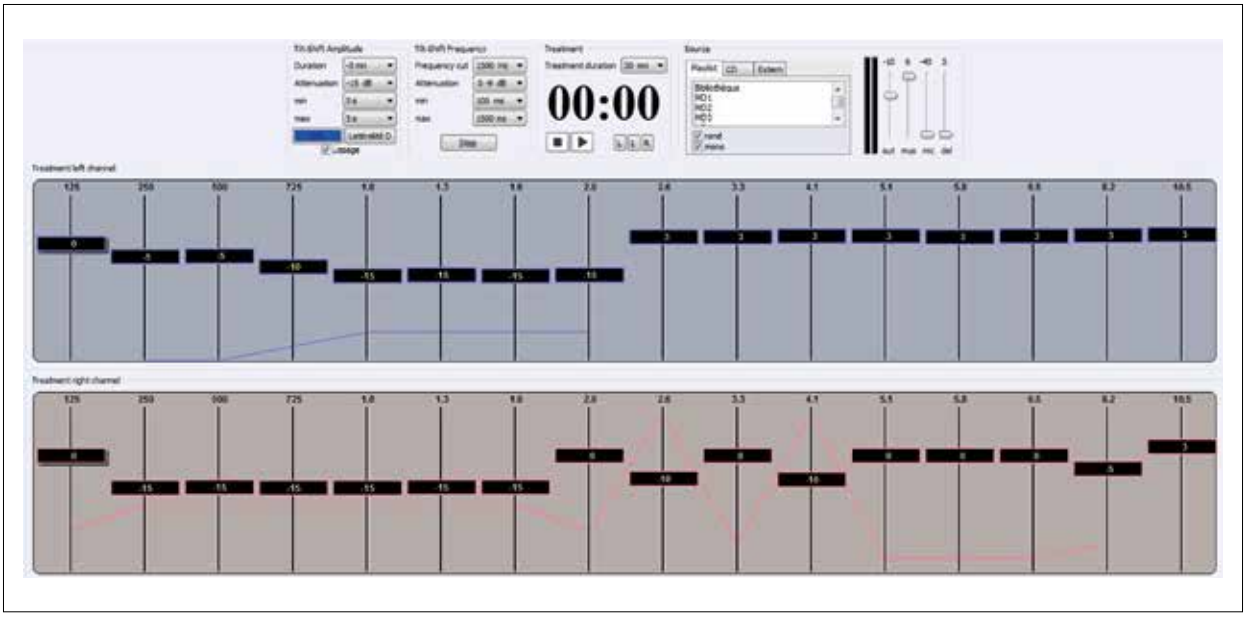

Figure 2. Graphic interface equalizer findings. **Above:** Left channel treatment. **Below:** Right channel treatment. Filtering for both ears are shown.

The AFAT program used music, which was previously selected according to four criteria: frequency, with a wide range of between 125–10,500 Hz or more; dynamics (ample, Δ-dB); musical tempo of between 110–140 beats per minute (bpm); and genre of instrumental music, including classical, jazz, and popular. Monophonic listening was used with an open-type headphone. The assessment of AFAT was performed using computer software that modified the selected tracks according to three elements: the tilt-shift frequency effect; frequency equalization; and tilt-shift of the right and left side. The details of these modifications in the AFAT program included the following:

The tilt-shift frequency effect: the device provoked sudden and unpredictable contrasts through the tonal change of the music. Thus, the hearing system was exposed alternately, and rapidly, to two opposite positions of filtering (high-pass filter and low-pass filter). Tilt-shifts, being unpredictable, were settled at ± 90 modulations/minute (min=100 ms – max=1500 ms).

Frequency equalization: the device integrated one equalizer for each ear. Equalizers, can increase or decrease the output level for each range of frequency as shown in Figure 2. Preference was given to stimulate lost frequencies or those in hollow dips. The higher hearing thresholds (peaks) were filtered while the lower hearing thresholds (hollows) were not modified or were only slightly amplified.

Tilt-shift right/left side effect: by using alternating right/left stimulation, preference was given to the affected ear (left). The average gap of hearing thresholds between the two ears was ≥15.30 dB-HL, and a volume reduction of -15 dB was applied for the right ear.

Indexed in: [PMC] [PubMed] [Emerging Sources Citation Index (ESCI)] [Web of Science by Clarivate]

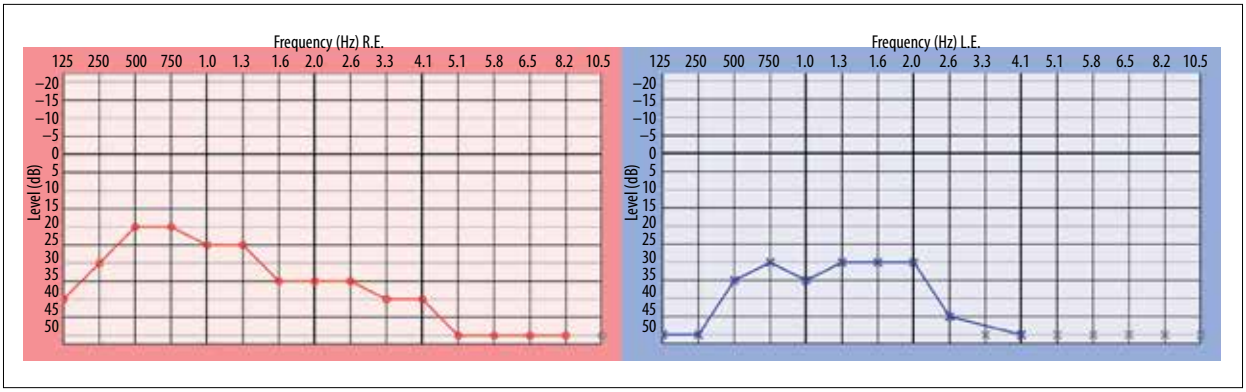

Figure 3. Audiogram findings, at the end of the alternating and filtering auditory training (AFAT) program. The average hearing gap between the two ears is reduced to ≥7.20 decibel (dB) hearing level (HL).

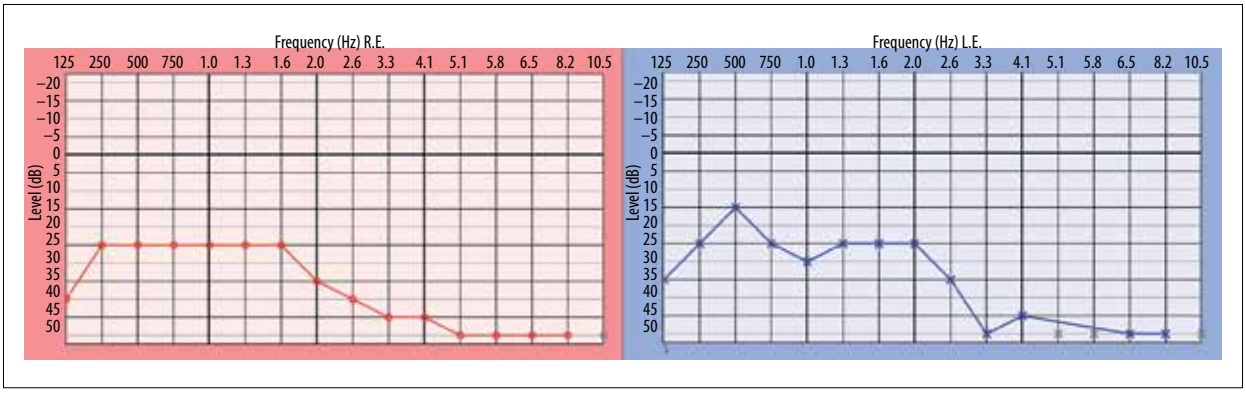

Figure 4. Audiogram findings, at one-month following the end of the alternating and filtering auditory training (AFAT) program. The average hearing gap between the two ears is reduced to ≥0.62 decibel (dB) hearing level (HL).

Patient outcome following neurorehabilitation including the AFAT protocol

Three weeks after the beginning of the AFAT program, the average hearing gap between the two ears was reduced to ≥7.20 dB-HL (Figure 3). During the psychiatric consultation, the patient showed clear and coherent speech and was well oriented. No symptoms of depression were found, except for slowed body movements and asthenia. The patient had no negative or depressive thoughts, and she was able to make plans for the future. At at three weeks after the beginning of the AFAT program, she was still underweight, weighing 38 kg (BMI=12.14).

One month after the end of the AFAT program, the patient was discharged from the hospital, and the average hearing gap between the two ears was reduced to ≥0.62 dB-HL (Figure 4). The average left hearing thresholds increased by ≥14.68 dB-HL compared with the audiogram before AFAT. The left ear showed a notable recovery of several thresholds frequencies, especially at low frequencies, as shown at 500 Hz (+35 dB-HL) and 250 Hz (+25 dB-HL). During the follow-up neurological consultation, she presented with much-improved body movements, improved temporospatial orientation, and a stable mood. Improvements were found in the following scales: FIM 80/126, BBS 45/56, and MMSE 28/30. At one-month follow-up, her body weight had increased by 7 kg to 45 kg (BMI=14.38).

At two-month follow-up after leaving the hospital, the patient was cooperative, her speech was correct and well structured, it was possible to discuss her work and she was able to communicate spontaneously. However, during the patient interview at this follow-up, she had some remaining emotional deficit and the FIM and Montreal Cognitive Assessment (MOCA) scores were 105/126 and 27/30, respectively. Evaluation of her balance showed no hypoesthesia and no disorders of her sense of balance. Assessment of her activities of daily living showed that she was independent during the day, but with assistance during the night. A summary of the evaluation of her physical function at follow-up and the Held and Pierrot-Desseilligny scale scores are shown in Table 2.

Discussion

The case presented in this report has demonstrated a link between improvement in hearing and improvement in balance in

Indexed in: [PMC] [PubMed] [Emerging Sources Citation Index (ESCI)] [Web of Science by Clarivate]

Table 2. Physiotherapy assessments performed at follow-up showing physical function and the Held and Pierrot-Desseilligny scale scores.

Physical functions	At follow-up examination
Ability to transfer	Autonomous
Ability to turn over	Autonomous
Balance while sitting	Autonomous
Balance while standing (bipodal)	Can stand for >2 minutes
Balance while standing (unipodal)	Can stand for 10 seconds with the eyes open
Walking	Autonomous in the day; assisted at night
Held and Pierrot-Desseilligny score	**At follow-up examination**
Upper limbs	4/5
Lower limbs	5/5

a patient who underwent neurorehabilitation following stroke, subarachnoid hemorrhage (SAH), and shunt-treated hydrocephalus. A previous study, using the National Health and Nutrition Examination Survey Database (2001–2004), showed that for each 10-decibel hearing level (dB-HL) of hearing loss, the risk of falls for an individual increased by 1.4 [9]. Applying this association to the ≥14.68 dB-HL increased left hearing thresholds in the patient presented in this report, balance recovery might have been associated with regain in hearing of the affected ear. Considering the complex clinical state of the patient described in this report, some important points must be considered. It is possible that the recovery in hearing and balance were associated with natural resolution following shunt-treated hydrocephalus. However, hearing loss can be a very long-term complication in patients with shunt-treated hydrocephalus [10].

Because the auditory system has both sensory and motor input, the link between the hearing recovery and the improved performance of the Functional Independence Measure (FIM), Berg Balance Scale (BBS), and Mini-Mental State Examination (MMSE) scores might be explained by the possible enhanced and intensified cerebral plasticity induced by the Alternating and Filtering Auditory Training (AFAT) protocol described in this case report.

It has previously been shown that regularly listening to music following a stroke can lead to structural reorganization in the recovering brain [4]. It must also be considered that visual hemispatial neglect is not necessarily associated with auditory neglect, and the two conditions might not be associated [11]. Therefore, it would be useful to conduct an audiometric and audiological examination in post-stroke and post-hydrocephalus patients to identify hearing impairment and to define a more accurate diagnosis leading to an appropriate intervention plan [12]. In addition to the possible link between balance and hearing recovery, early auditory stimulation after a stroke should be recommended to improve neural organization in the recovering brain [4]. Early auditory stimulation after a stroke would also help to avoid maladaptive auditory cortex reorganization following unilateral sensorineural hearing loss (SNHL) [13].

This case report has shown that AFAT represents a noninvasive and inexpensive treatment and has no side effects or adverse reactions to medications or other diseases. Even though the AFAT program is at an early stage of development, this and other individualized music-based auditory forms of neurorehabilitation should be investigated further in patients with different types of hearing loss, as it is safe and inexpensive and can be easily incorporated into the neurorehabilitation process.

Conclusions

To the knowledge of the authors, this is the first reported case linking the restoration of balance and hearing following subarachnoid hemorrhage (SAH) and shunt-treated hydrocephalus. The findings of this case support the importance of the benefits of assessment of hearing in this group of patients, and supports the benefit of a multidisciplinary, complementary, personalized approach, such the alternating and filtering auditory training (AFAT) protocol, which can be integrated standard neurorehabilitation, to improve both hearing perception and recovery of balance. This case also supports the need for further studies into the role of auditory function on balance disorders and cognitive function.

Acknowledgments

The authors thank Dr. Jean-Michel Issartel for providing the material for the Alternating and Filtering Auditory Training (AFAT) protocol.

Conflicts of interests

None.

Indexed in: [PMC] [PubMed] [Emerging Sources Citation Index (ESCI)] [Web of Science by Clarivate]

References:

1. Horak FB: Postural orientation and equilibrium: What do we need to know about neural control of balance to prevent falls? Age Ageing, 2006; 35–S2: ii7–ii11
2. Chen DS, Genther DJ, Betz J, Lin FR: Association between hearing impairment and self-reported difficulty in physical functioning. J Am Geriatr Soc, 2014; 62: 850–56
3. Satzer D, Guillaume DJ: Hearing loss in hydrocephalus: A review, with focus on mechanisms. Neurosurg Rev, 2016; 39: 13–24
4. Särkämö T, Ripollés P, Vepsäläinen H et al: Structural changes induced by daily music listening in the recovering brain after middle cerebral artery stroke: A voxel-based morphometry study. Front Hum Neurosci, 2014; 8: 245
5. Ripollés P, Rojo N, Grau-Sánchez J et al: Music supported therapy promotes motor plasticity in individuals with chronic stroke. Brain Imaging Behav, 2016; 10: 1289–307
6. Sekiya K, Fukushima M, Teismann H et al: Neuro-rehabilitation approach for sudden sensorineural hearing loss. J Vis Exp, 2016; (107): e53264
7. Han LA, Poulsen T: Equivalent threshold sound pressure levels for Sennheiser HDA 200 earphone and Etymotic Research ER-2 insert earphone in the frequency range 125 Hz to 16 kHz. Scandin Audiol, 1998; 27(2): 105–12
8. ISO 389–8 Acoustics – Reference zero for the calibration of audiometric equipment - Part 8: Reference equivalent of threshold sound-pressure levels for pure tones and circum-aural headphones. International Organisation for Standardisation: Geneva, Switzerland. 2001. Available from: URL: *https://www.iso.org/obp/ui/fr/#iso:std:iso:389:-8:ed-1:v1:en*
9. Lin FR, Ferrucci L: Hearing loss and falls among older adults in the United States. Arch Intern Med, 2012; 172: 369–71
10. Panova MV, Geneva IE, Madjarova KI, Bosheva MN: Hearing loss in patients with shunt-treated hydrocephalus. Folia Med, 2015; 57(3–4): 216–22
11. Spierer L, Meuli R, Clarke S: Extinction of auditory stimuli in hemineglect: Space versus ear. Neuropsychologia, 2007; 45(3): 540–51
12. Koohi N, Vickers DA, Lakshmanan R et al: Hearing characteristics of stroke patients: prevalence and characteristics of hearing impairment and auditory processing disorders in stroke patients. J Am Acad Audiol, 2017; 28(6): 491–505
13. Okamoto H, Fukushima M, Teismann H et al: Constraint-induced sound therapy for sudden sensorineural hearing loss – behavioral and neurophysiological outcomes. Audiol, 2017; 28: 491–505

Indexed in: [PMC] [PubMed] [Emerging Sources Citation Index (ESCI)] [Web of Science by Clarivate]