

‘PREHAB’: Vestibular prehabilitation to ameliorate the effect of a sudden vestibular loss

Måns Magnusson*, Mikael Karlberg and Fredrik Tjernström

Department of Otorhinolaryngology and Neurosurgery, Lund University Hospital, Lund, Sweden

Abstract. A sudden unilateral loss or impairment of vestibular function causes vertigo, dizziness and impaired postural function. In most occasions, everyday activities supported or not by vestibular rehabilitation programs will promote compensation and the symptoms subside. As the compensatory process requires sensory input, matching performed motor activity, both motor learning of exercises and matching to sensory input are required. If there is a simultaneous cerebellar lesion found during surgery of the posterior cranial fossa, there may be a risk of a combined vestibulo-cerebellar lesion, with reduced compensatory abilities and with prolonged or sometimes permanent disability. On the other hand, a slow gradual loss of unilateral function occurring as the subject continues well everyday activities may go without any prominent symptoms.

We therefore implemented a pre treatment plan before planned vestibular lesions (prehab). This was first done in subject undergoing gentamicin treatment for Meniere’s disease (MD). Subjects perform vestibular exercises for 14 days before the first gentamicin installation and then continue doing so until free of symptoms. Most subjects would only experience slight dizziness while losing vestibular function. We then expanded the approach to patients with brainstem tumours requiring surgery but with remaining vestibular function to ease postoperative symptoms and reduce risk of combined cerebello-vestibular lesions.

This patient group was given gentamicin installations trans-tympanically before tumour surgery and then underwent prehab. In all cases there was a caloric loss, loss of VOR evident in the head impulse tests, impaired subjective vertical and horizontal, and reduced caloric function induced by the pre-surgery gentamicin treatment. The prehab eliminated spontaneous and positional nystagmus, subjective symptoms, and postural function up before surgery and allowed for rapid postoperative recovery.

The concept of ‘pre-lesion rehabilitation’ where training is introduced before a planned lesion and if possible paralleled with a gradual function loss expands the potential of rehabilitation. Here it was used for vestibular lesions but it is possible that similar approaches may be developed for other situations, which include foreseeable loss of function.

Keywords: Vestibular, compensation, prehab, rehabilitation, schwannoma, recovery

1. Introduction

Rehabilitation procedures aim to either train and recover or substitute functions that have been lost. Depending on the lesions addressed, there is a plethora of methods and strategies. This process of adaptation and habituation is a process of physiological learning with biological underpinnings as the patient strives to adapt to new situations or circumstance brought about by injury or illness.

A sudden unilateral loss or impairment of vestibular function results in the well known symptoms of vertigo, nausea and ataxia. In normal healthy individuals most symptoms subside over weeks to months due to central nervous compensation and re-calibration largely from cerebellar action [1]. Where there is no or insufficient restitution of function, certain deficits remain and the patients will suffer from imbalance and fatigue [2,3]. Patients with additional central nervous disorders and older patients often face problems compensating the vestibular loss and in situations where the vestibular loss coincide with cerebellar lesions, the compensatory process may be prolonged or incomplete [1–3]. Normal vestibular compensation may be compared to a learn-

*Corresponding author: Mans Magnusson, Dept of Otorhinolaryngology, Lund University, Lund University Hospital, 221 85 Lund, Sweden. E-mail: mans.magnusson@med.lu.se.

ing process, [4,5], where the sensory input from vision, proprioception, and vestibular receptors are interpreted, re-weighted and re-calibrated [2,5]. It is now accepted that training or exposure enhance this process, and that such movements combined into a vestibular rehabilitation program may be used to accelerate recovery [2, 6]. In general, rehabilitation therapy contains both motor learning and a sensory recalibration component, introducing movements that present a sensory mismatch but with a reference stable enough to form a base for a new calibration [2,4,6,7]. However, the medically compromised or older patient may have both difficulties and suffer from insufficient recovery from traditional vestibular rehabilitation. To meet the challenge with patients with incapacitating Meniere's disease and simultaneous anticipated reduced ability of compensation we developed a pre-treatment program, where the motor performance were trained in advance with the aim of gaining motor learning and then gentamicin was administered while continuing the exercises during the gradual loss of function [7–9].

Also in cases in need of cerebellopontine angle (CPA) or posterior fossa surgery, it is beneficial for the patient to receive rehabilitation pre-operatively before vestibular function is compensated. Because of such consideration we applied the concept of vestibular prehabilitation (prehab) when faced with patients that needed vestibular ablation (from medicines or surgery) and in whom there would be additional challenges to post-treatment or post-operative rehabilitation alone [2, 7,8]. The rationale being, hopefully, to initiate and promote the learning processes on a cellular level [7,8]. The patients started training 14 days before a planned vestibular ablation with gentamicin, learning the movements and enhancing the compensatory process. Intense training would then allow for compensation as function was being lost. In the majority of patients with larger CPA tumours, the vestibular function is lost before surgery and compensation has already taken place. But in smaller tumours or in more medial placed ones and meningiomas, there might be remaining vestibular function. These patients will experience the symptoms of an acute vestibular loss postoperatively, simultaneously with recovering from the surgery. In tumours compromising the cerebellum, surgical procedures may interfere with the cerebellum itself. If such patients, as well as the elderly patients, have remaining vestibular function, the recovery may be impeded. Furthermore, in younger patients with reduced vestibular function in rotation and caloric tests, there might still be remnant function in other parts of the vestibular labyrinth that will cause postoperative dizziness and imbalance.

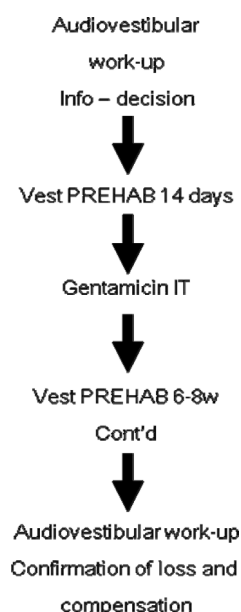


Fig. 1. Program for gentamicin treatment with vestibular rehab.

Our prehab program is now utilized in patients undergoing vestibular ablation with gentamicin for Meniere's disease and in advance of surgery, to avoid post-operative vertigo and symptoms of acute vestibular loss, when recovering from an intracranial procedure.

2. Material and methods

The program developed from treatment of patients with incapacitating Meniere's disease planned for ablation with gentamicin. These patients were informed and instructed to perform a rehab program at home for at least 14 days before treatment and continue after gentamicin was installed to the middle ear. This procedure has now become routine in our facility for all patients undergoing gentamicin treatment [8,9], as well as in occasional cases of labyrinthectomy.

We studied 12 patients with CPA tumor who underwent preoperative gentamicin ablation and prehab. There were 7 male and 5 females (mean age 50 age range 22–72 years of age). All of these patients had CPA tumours planned for surgery and significant remaining vestibular function. Pre-treatment vestibular function was tested with video impulse test of all 3 canals of each ear, bi-thermal calorics, VEMP, subjective horizontal and vertical, rod and frame tests, posturography and audiometry with pure tone and speech discrimination evaluation as has been previously described. [10]. Assessments were approved by the lo-

cal ethics committee and all patients were informed and consented to the program. After evaluation, information and decision on surgery, the patients were instructed to execute the home based vestibular training program adopted for patients with acute vestibular loss and used as the same vestibular 'prehab' as is used in patients treated with gentamicin for Meniere's disease. The 'prehab' constituted of 14 days of training after which gentamicin was installed in the middle ear on the tumour side. Patients received 3–4 transtympanic injections of approximately 0.3–0.4 ml of gentamicin at each installation over 2 consecutive days. The training continued during installations and afterwards as the ototoxic effect of the gentamicin gradually took effect [8]. During the series it was found that a repetition rate of 3 times daily, for at least 6 weeks after instalments of gentamicin was sufficient for achieving vestibular compensation [11].

With the aim to ensure vestibular loss and compensation, the patients were again tested after 6 weeks or later. Then patients continued the training program until surgery and were encouraged to continue the first postoperative weeks.

3. Results

Patients with Meniere's disease most often reported no or very little dizziness after gentamicin instillation [8,9]. Among the patients planned for CPA surgery, a total or near total loss of vestibular function and a compensated vestibular ocular reflex was achieved in all 12 patients before surgery [10]. There was no significant spontaneous, gaze or positional nystagmus and patients reported no postural impairments at pre-surgery work-up. In two patients there was deterioration of hearing but in one patient hearing improved from a PTA of 36 dB and 84% discrimination to 25dB and 96% discrimination. All patients recovered from surgery and could be transferred to the ward the day after surgery. The majority of patients were able to walk on their own on the first postoperative day. These patients responded in a similar fashion to our Meniere's disease prehab cohort with only slight to moderate dizziness, after 5 to 7 days. In most cases patients return to work within 2 weeks after treatment. A few patients, with office work, returned to work even sooner. In addition, patients that had received prehab treatment with gentamicin had better long time postural abilities with lesser sway than those that did not [12].

4. Discussion

To ameliorate the effect of a planned but still sudden loss of vestibular function, a concept of pre-lesion rehabilitation (prehab) was introduced. The concept included movement training before a planned lesion and with continuation of the program in parallel with the gradual function loss caused by the effect of transtympanic gentamicin instalments in advance of planned removal of CPA tumours and consequent section of the vestibular nerve or in cases of incapacitating Meniere's disease. With the strategy of including vestibular prehab, developed for gentamicin therapy, patients were well compensated and vestibular ablated in as short time span as 6–8 weeks. Post surgery there was no or very little dizziness and little imbalance reported.

In an acute vestibular lesion vestibular training programs are effective to promote and speed up recovery [2,6]. These programs commonly include rotational and other dynamic movements that challenge the vestibular reflexes. The rationale is to create or increase a sensory mismatch to enforce the re-calibration of the reflexes on a cellular level [2,6,7]. A gradual loss of vestibular function on the other hand, may not produce very much subjective symptoms, as commonly seen in patients who have had a vestibular loss due to a slowly growing CPA tumour. Hence, by combining a vestibular training program with an induced gradual vestibular decline [8–10] it should be possible to achieve a vestibular loss without too much discomfort for the patient [8]. In addition, such a program would allow for compensation older subjects and patients with at least minor central nervous impairments.

Patients treated with intratympanic gentamicin for incapacitating Meniere's disease since the program was introduced in 1992, report generally only a slight to moderate dizziness at 5 to 7 day time point. In most cases these individuals returned to work within 2 weeks after treatment. This procedure has now become routine in our facility for all patients undergoing gentamicin treatment because of incapacitating Meniere's disease, as well as in the occasional cases planned for a labyrinthectomy.

Rehabilitation techniques generally include repetitive motor tasks with an intention to create the needed strength, co-ordination or motor control for certain functions. In vestibular rehab the subjects perform movement to induce vestibular sensory input to enhance the sensory mismatch caused by the primary deficit and facilitate a re-calibration. Here, the initial idea to begin training before a planned lesion was to let the

subject become familiar with and learn to execute the motor tasks of the training program i.e. induce motor learning, and to attempt to optimize the function of the vestibular and postural reflexes. Simultaneously, it was hypothesized that if this training would enhance and modulate calibration per se, than the central nervous system would be primed and better set for further learning and recalibration after the planned lesion. Hopefully, one would initiate motor learning on the cellular level in advance of the lesion. Recent research corroborate such ideas as it has provided support for multiple plasticity mechanisms in learning and cerebellar adaptation [13] and a bi-directional plasticity in cerebellar purkinje cells suggesting a mirror image of the learning process at hippocampal synapses [14]. There is also evidence that specific training but not mere motor activity may increase the number of synapses and cause astrocytic hypertrophy of the cerebellum [15,16]. These reports support that it could be possible that pre-lesion training of the prehab may enhance the learning ability also on the cellular level. Such anticipative approaches may be of even more important in patients with CPA tumours and other disorders and tumours of the posterior fossa compromising the cerebellum but with a normal pre-treatment vestibular function. In such cases surgery may produce a combined vestibular and cerebellar lesion. In such cases recovery could be prolonged and incomplete and the patient may suffer permanent disability. With the combined gentamicin-prehab program used in our lab we have the possibility to ablate vestibular function and achieve compensation before surgery, avoiding such fearful complications.

5. Conclusion

We describe our use of per-treatment vestibular rehabilitation (prehab) before planned vestibular ablation in Meniere's disease and together with the pre-surgery gentamicin ablation where intracranial surgery will induce an acute vestibular loss. Both groups show gradual but steady reduction in vestibular dysfunction with earlier return to work when compared to patients who do not receive prehab. This concept of 'pre-lesion rehabilitation' where training is introduced before the planned lesion and if possible paralleled with a gradual function loss expands the potential of rehabilitation. In the present series it was used for vestibular lesions but it is possible that similar approaches may be developed for other situations, which include foreseeable loss of function.

References

- [1] P.P. Vidal, C. de Waele, N. Vibert and M. Mühlethaler, Vestibular compensation revisited, *Otolaryngol Head Neck Surg* **119**(1) (Jul 1998), 34–42.
- [2] M. Lacour, Restoration of vestibular function: basic aspects and practical advances for rehabilitation, *Curr Med Res Opin* **22**(9) (Sep 2006), 1651–1659.
- [3] J.M. Furman, C.D. Balaban and I.F. Pollack, Vestibular compensation in a patient with a cerebellar infarction, *Neurology* **48**(4) (Apr 1997), 916–920.
- [4] F. Tjernström, P.A. Fransson, A. Hafström and M. Magnusson, Adaptation of postural control to perturbations—a process that initiates long-term motor memory, *Gait Posture* **15**(1) (Feb 2002), 75–82.
- [5] J. Schouenborg, Somatosensory imprinting in spinal reflex modules, *J Rehabil Med* (41 Suppl) (May 2003), 73–80.
- [6] H.S. Cohen, Disability and rehabilitation in the dizzy patient, *Curr Opin Neurol* **19**(1) (Feb 2006), 49–54.
- [7] D.A. Jirenhed, F. Bengtsson and G. Hesslow, Acquisition, extinction, and reacquisition of a cerebellar cortical memory trace, *J Neurosci* **27**(10) (7 Mar 2007), 2493–2502.
- [8] M. Magnusson, E.-M. Malmström and M. Karlberg, Pretreatment vestibular rehabilitation for patients undergoing vestibular ablation, *The 16th Danavox Symposium on Meniere's Disease*, 1995.
- [9] M. Magnusson and S. Padoan, Delayed onset of ototoxic effects of gentamicin in treatment of Meniere's disease. Rationale for extremely low dose therapy, *Acta Otolaryngol* **111**(4) (1991), 671–676.
- [10] M. Magnusson, B. Kahlon, M. Karlberg, S. Lindberg and P. Siesjö, Preoperative vestibular ablation with gentamicin and vestibular 'prehab' enhance postoperative recovery after surgery for pontine angle tumours—first report, *Acta Otolaryngol* **127**(12) (Dec 2007), 1236–1240.
- [11] F. Tjernström, P.-A. Fransson and M. Magnusson, Improved postural control through repetition and consolidation, *Journal of Vestibular Research: Equilibrium & Orientation* **15**(1) (2005), 31–39.
- [12] F. Tjernström, P.-A. Fransson, B. Kahlon, M. Karlberg, S. Lindberg, P. Siesjö and M. Magnusson, Vestibular PREHAB and gentamicin before schwannoma surgery may improve long-term postural function, *Journal of Neurology Neurosurgery and Psychiatry* **80**(11) (2009), 1254–1260.
- [13] E.S. Boyden, A. Katoh and J.L. Raymond, Cerebellum-dependent learning: the role of multiple plasticity mechanisms, *Annu Rev Neurosci* **27** (2004), 581–609.
- [14] H. Jörntell and C. Hansel, Synaptic memories upside down: bidirectional plasticity at cerebellar parallel fiber-Purkinje cell synapses, *Neuron* **52**(2) (19 Oct 2006), 227–238.
- [15] J.A. Kleim, K. Vij, D.H. Ballard and W.T. Greenough, Learning-dependent synaptic modifications in the cerebellar cortex of the adult rat persist for at least four weeks, *Neurosci* **17**(2) (15 Jan 1997), 717–721.
- [16] J.A. Kleim, J.A. Markham, K. Vij, J.L. Freese, D.H. Ballard and W.T. Greenough, Motor learning induces astrocytic hypertrophy in the cerebellar cortex, *Behav Brain Res* **178**(2) (28 Mar 2007), 244–249. Epub 2007 Jan 25.