Literature Review

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Rehabilitation of unilateral hearing loss by implantable hearing aids: systematic review

Reabilitação de perdas auditivas unilaterais por próteses auditivas implantáveis: revisão sistemática

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ABSTRACT

Introduction: The binaural hearing is the proper condition that allows the listener the depth dimension and sonority necessary to the perception of the soundworld. **Objective:** To determine, through a systematic review, the benefits that implantable hearing aids bring to adult individuals who have unilateral hearing loss in terms of localization of sound source and speech recognition in the presence of noise. **Research strategy:** Were used combinations of seven Portuguese descriptors indexed in Health Sciences (DeCS), and in English indexed in the Medical Subject Headings (MeSH), being: Adult, Unilateral Hearing Loss, Hearing Aids, Bone Conduction, Cochlear Implant We conducted a survey of the PubMed, Cochrane, LILACS, and Science Direct databases of articles published between January 2005 and September 2015. **Selection criteria:** Survey participants over 18 years old with unilateral hearing loss, who used implantable hearing aid bone anchored hearing aids or cochlear implantation) and who had been submitted to the evaluation of the location of the sound source or performance of speech recognition in the presence of noise before and After implantation. **Results:** Of the 21 articles analyzed, seven were experimental; six were prospective, three descriptive, four case series and one case study. **Conclusion:** Despite the great clinical heterogeneity observed among the studies that evaluated the auditory rehabilitation of patients with unilateral hearing loss, it is possible to conclude that the cochlear implant provides better results both for the localization of the sound source and for speech recognition in the presence of noise.

Keywords: Hearing loss, Unilateral; Cochlear implantation; Bone conduction; Hearing aids

RESUMO

Introdução: A audição binaural é a condição adequada que permite ao ouvinte a dimensão de profundidade e sonoridade necessárias à percepção do mundo sonoro. **Objetivo:** Determinar, por meio de uma revisão sistemática, quais os benefícios que as próteses auditivas implantáveis trazem para indivíduos adultos que possuem perda auditiva unilateral, no que se refere às habilidades de localização da fonte sonora e do reconhecimento de fala na presença do ruído. **Estratégia de pesquisa:** Foram utilizadas combinações de sete descritores em português, indexados no Descritores em Ciências da Saúde (DeCS), e em inglês, indexados no *Medical Subject Headings* (MeSH), sendo eles: Adulto, Perda Auditiva Unilateral, Auxiliares de Audição, Condução Óssea, Implante Coclear, Idoso, Reabilitação *Adult, Hearing Loss Unilateral, Bone Conduction, Cochlear Implantation, Rehabilitation, Elderly* e *Hearing Aid*. Foi realizada uma pesquisa nas bases de dados PubMed, Cochrane, LILACS e Science Direct de artigos publicados entre janeiro de 2005 e setembro de 2015. **Critérios de seleção:** Participantes da pesquisa com mais de 18 anos de idade, com perda auditiva unilateral, que utilizavam prótese auditiva implantável (prótese auditiva ancorada no osso ou implante coclear) e que tivessem sido submetidos à avaliação de localização da fonte sonora ou desempenho de reconhecimento de fala na presença de ruído, antes e depois da implantação. **Resultados:** Dos 21 artigos analisados, sete foram experimentais, seis prospectivos, três descritivos, quatro séries de casos e um estudo de caso. **Conclusão:** Apesar da grande heterogeneidade clínica observada entre os estudos que avaliaram a reabilitação auditiva de pacientes com perda auditiva unilateral, é possível concluir que o implante coclear fornece melhores resultados, tanto para a habilidade de localização da fonte sonora, como do reconhecimento de fala na presença de ruído.

Palavras-chave: Perda auditiva unilateral; Implante coclear; Condução óssea; Auxiliares de audição

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INTRODUCTION

Individuals with unilateral hearing loss represent a challenge for physicians and speech-language pathologists who work with auditory rehabilitation. In the past, people with this type of loss accepted the lack of resources and did not invest in rehabilitation, believing that a functioning ear was sufficient and that would ensure good audibility and understanding.

Currently, with the advancement of auditory evaluation technology and the miniaturization of electronic devices, this reality is changing. It is known that the communication difficulties related to unilateral hearing loss are great and involve problems with the sound source localization, the temporal processing of information and the difficulties of understanding in degraded environments, in the presence of competitive noise, or in the interlocution with more than two people[1,2,3].

Listening with both ears, therefore, is an ideal condition, which gives the listener the dimension of depth and sonority necessary for the perception of the sound world[4,5,6].

As treatment options for unilateral hearing loss, it is mentioned the old CROS system (Contralateral Routing Signal)[7], which is still used today and can easily be adapted in behind the ear hearing aids; the bone anchored hearing aids[8] and the cochlear implant[9].

The CROS system consists of a pair of behind the ear hearing aids, fitted in both ears. The device placed behind the bad ear picks up the sound and sends it via the Bluetooth system to the other ear, which will treat the signal naturally. As the user of this system necessarily needs a prosthesis with microphone adapted in the bad ear and another one with the receiver in the better ear, many patients do not adhere to the treatment, even for aesthetic and practical reasons[7].

The bone anchored hearing aid (BAHA) is an osseointegrated implant, which transmits the sound directly to the inner ear, transposing the impedance of the skin and subcutaneous tissue. It is indicated for mixed and/or conductive hearing loss and also for unilateral hearing loss[8]. In the latter case, the BAHA is surgically adapted behind the ear with hearing loss and stimulates the contralateral ear through bone conduction.

The cochlear implant (CI) is a device that provides accessibility to environmental and speech sounds. This is a computerized prosthesis, consisting of an internal and an external component, capable of partially replacing the sensory organ of the hearing, providing electrical impulses to stimulate the remaining neural fibers of the injured cochlea[10].

The use of implantable prostheses, either the CI or the BAHA, is recent in the rehabilitation of unilateral hearing loss and has been provoking discussions in the academic and scientific milieu of the physicians and speech-language pathologists.

OBJECTIVE

The objective of this study was to determine, through a systematic review (SR), what benefits the implantable hearing aids bring to adult individuals with unilateral hearing loss, regarding the abilities of sound source localization and the recognition of speech in the presence of noise.

RESEARCH STRATEGY

The guiding question of this SR was: Are implantable hearing aids effective for improving auditory perception?

The search strategy was based on combinations of seven Portuguese descriptors indexed in the Health Sciences Descriptors (DeCS) and in English, indexed in the Medical Subject Headings (MeSH) (Chart 1).

The databases selected for the survey were: PubMed, Cochrane, LILACS, and Science Direct. The articles considered for the study were those published between January 2005 and September 2015, in any language. The protocol of analysis of the articles included in the study was as follows:

Subjects: individuals over 18 years of age, with unilateral hearing loss.

Type of intervention: use of implantable hearing aid (BAHA or CI).

Comparison: evaluation of sound source localization results or speech recognition performance in the presence of noise, before and after implantation.

Chart 1. Descriptors used in the systematic review

Search strategy **Descriptors in Portuguese (DecS)**	Search strategy **Descriptors in English (MeSH)**
Adulto x Perda Auditiva Unilateral x Auxiliares de Audição	Adult x Hearing Loss Unilateral x Hearing Aid
Adulto x Perda Auditiva Unilateral x Condução Óssea	Adult x Hearing Loss Unilateral x Bone Conduction
Adulto x Perda Auditiva Unilateral x Implante Coclear	Adult x Hearing Loss Unilateral x Cochlear Implantation
Adulto x Perda Auditiva Unilateral x Reabilitação	Adult x Hearing Loss Unilateral x Rehabilitation
Idoso x Perda Auditiva Unilateral x Auxiliares de Audição	Elderly x Hearing Loss Unilateral x Hearing Aid
Idoso x Perda Auditiva Unilateral x Condução Óssea	Elderly x Hearing Loss Unilateral x Bone Conduction
Idoso x Perda Auditiva Unilateral x Implante Coclear	Elderly x Hearing Loss Unilateral x Cochlear Implantation
Idoso x Perda Auditiva Unilateral x Reabilitação	Elderly x Hearing Loss Unilateral x Rehabilitation

Type of outcome: improvement of hearing in the presence of noise, or improvement of the sound source localization ability.

Type of study: clinical trial, experimental, prospective, descriptive, case series, and cohort study.

The period of auditory deprivation and hearing loss etiology were also analyzed.

SELECTION CRITERIA

Inclusion criteria: studies with research participants with at least 18 years of age who used implantable hearing aid, BAHA or CI, who were submitted to the sound source localization and/or speech recognition in the presence of noise tests, preimplantation and post implantation, being the type of studies clinical, experimental, prospective, descriptive, case series, and cohort.

Exclusion criteria: studies without interventions, studies with individuals with bilateral hearing loss, even asymmetrical, and studies with special groups with other impairments such as cerebral palsy or syndromes.

The selection of studies was performed in stages, as shown in Figure 1.

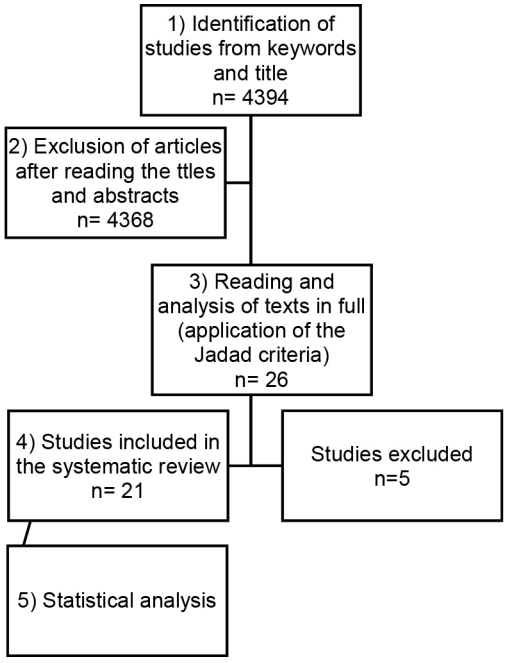

Figure 1. Stages of the systematic review

DATA ANALYSIS

Initially, two judges analyzed the titles of the articles found in the databases with the aforementioned combinations and selected the articles that met the SR eligibility criteria. To verify the degree of agreement of the evaluations, the Kappa test was used, in which the value was 0.628 with a value of $p < 0.001$, and there was, therefore, a significant agreement among the evaluators. At this stage, 4394 articles were identified in total, of which 4368 did not meet the selection criteria and were excluded.

Therefore, 26 articles remained, which were then read in full by the two judges, both speech therapists. At this stage, the Jadad Criterion[11] was used as a tool for analyzing the quality of the articles and it is based on five questions: 1) Was the study described as randomized? 2) Has randomization been described and is it adequate? 3) Were there any comparisons of results? 4) The comparisons of results have been described and are suitable? 5) Have losses and exclusions been described? Each positive response counted 1 point and the article was discarded when the score was less than 3. Five articles were excluded at this stage. Finally, 21 articles were analyzed and began to compose the present SR.

A descriptive analysis of the results was performed, but due to the heterogeneity of the data, it was not possible to perform the meta-analysis.

RESULTS

Of the 21 articles analyzed (Chart 2), 7 were experimental, 6 prospective, 3 descriptive, 4 case series and 1 case study. None of the studies were conducted as a randomized controlled trial and neither tested a control group.

Of the 21 articles selected, 11 evaluated the performance of subjects who used BAHA and 10 evaluated the performance of subjects submitted to CI.

In all studies with subjects with CI, there was improvement in the sound source localization, while the majority of BAHA users did not show improvement in the performance of this ability.

The outcomes observed in the studies selected for the sound source localization ability are shown in Table 1, and 14 articles addressed this theme with a total of 201 subjects investigated.

Almost half of the studies were conducted in the United States (9). Three studies were conducted in Italy, 2 studies in Germany and 2 studies in Belgium.

The time of auditory deprivation occurred between 3 months and 64 years, while the age of the subjects submitted to hearing implants ranged from 16 to 75 years.

The causes of the unilateral hearing loss reported in the studies were, most frequently, Meniere's disease, Acoustic Neuroma, Cholesteatoma and Sudden Deafness.

Most of the tests used to verify speech recognition and sound localization were not standardized. The most widely used test for measuring speech recognition was the Hearing in Noise Test (HINT).

The outcomes for the speech recognition ability in the presence of noise, with 14 articles addressing this theme in a total of 185 investigated subjects, are described in Table 2. Of the 14 studies, only 1, which evaluated BAHA users, did not find improvement in the speech recognition ability.

Chart 2. Articles that composed the systematic review

Nº	Year	Article title	Authors	Journal	Intervention	Test
1	2009	Efficacy of the bone-anchored hearing aid for single-sided deafness	Linstrom et al.[12]	The Laryngoscope	BAHA	HINT
2	2009	Binaural hearing after cochlear implantation in subjects with unilateral sensorineural deafness and tinnitus	Vermeire et al.[13]	Audiol Neurotol	CI	LIST
3	2009	Management of single-sided deafness with the bone-anchored hearing aid	Yuen et al.[14]	Otolaryngology–Head and Neck Surgery	BAHA	Non-standardized
4	2010	Hearing and quality of life in a south European BAHA population	Barbara et al.[15]	Acta Oto-Laryngologica	BAHA	Non-standardized
5	2010	Bone-anchored hearing aids in patients with acquired and congenital unilateral inner ear deafness (Baha CROS): linical evaluation of 56 Cases	Hol et al.[16]	Annals of Otology, Rhinology & Laryngology	BAHA	Non-standardized
6	2011	Speech recognition with BAHA simulator in subjects with acquired unilateral sensorineural hearing loss	Bovo et al.[17]	Acta Oto-Laryngologica	BAHA	Non-standardized
7	2012	Auditory abilities after cochlear implantation in adults with unilateral deafness: a pilot study	Firszt et al.[18]	Otol Neurotol	CI	Non-standardized
8	2012	Horizontal plane localization in single-sided deaf adults fitted with a bone-anchored hearing aid (Baha)	Grantham et al.[19]	Ear & Hearing	BAHA	Non-standardized
9	2012	Cochlear implant in the treatment of incapacitating unilateral tinnitus: case report	Mendes et al.[20]	International Tinnitus Journal	CI	Non-standardized
10	2012	Outcome of bone-anchored hearing aids for single-sided deafness: A prospective study	Pai et al.[21]	Acta Oto-Laryngologica	BAHA	Non-standardized
11	2013	Sound localization in unilateral deafness with the Baha or TransEar device	Battista et al.[22]	Jama Otolaryngol Head Neck Surg	BAHA	Non-standardized
12	2013	Outcomes following cochlear implantation for patients with single-sided deafness, including those with recalcitrant Ménière's disease	Hansen et al.[23]	Otol Neurotol	CI	CNC e ZbIO
13	2013	Clinical outcome after cochlear implantation in patients with unilateral hearing loss due to labyrinthitis ossificans	Hassepass et al.[24]	Otology & Neurotology	CI	Hochmair-Schulz-Moser e Oldenburg
14	2013	Tinnitus in a single-sided deaf ear reduces speech reception in the nontinnitus ear	Mertens et al.[25]	Otology & Neurotology	CI	LIST
15	2013	Cochlear implantation for unilateral deafness with and without tinnitus: a case series	Tavora-Vieira et al.[26]	The Laryngoscope	CI	BKB-SIN
16	2013	Comparison of speech discrimination in noise and directional hearing with 2 different sound processors of a bone-anchored hearing system in adults with unilateral severe or profound sensorineural hearing loss	Wesarg et al.[27]	Otology & Neurotology	BAHA	Non-standardized
17	2014	Long-term subjective benefit with a bone conduction implant sound processor in 44 patients with single-sided deafness	Desmet et al.[28]	Otology & Neurotology	BAHA	Non-standardized
18	2014	An initial experience of cochlear implantation for patients with single-sided deafness after prior osseointegrated hearing device	Erbele et al.[29]	Otology & Neurotology	CI	Non-standardized
19	2014	Localization and interaural time difference (ITD) thresholds for cochlear implant recipients with preserved acoustic hearing in the implanted ear	Gifford et al.[30]	Hearing Research	CI	Non-standardized
20	2015	Interaural level difference cues determine sound source localization by single-sided deaf patients fit with a cochlear implant	Dorman et al.[31]	Audiol Neurotol	CI	Non-standardized
21	2015	Bone conductive implants in single-sided deafness	Monini et al.[32]	Acta Oto-Laryngologica	BAHA	WRS

Table 1. Outcomes verified with implantable prostheses for the sound source localization ability (n=14)

	Articles (n=14)		Total of subjects (n=201)	
	n	%	n	%
BAHA				
Improved	5	36	62	30.8
No improvement	3	21	75	37.4
CI				
Improved	6	43	64	31.8
No improvement	-	-	-	-
Total	14	100	201	100

Subtitle: BAHA = Bone Anchored Hearing Aid; CI = Cochlear Implant

Table 2. Outcomes verified with implantable prostheses for the speech recognition ability in the presence of noise (n=14)

	Articles (n=14)		Total de subjects (n=185)	
	n	%	n	%
BAHA				
Improved	7	50.0	124	67.0
No improvement	1	7.2	11	6.0
CI				
Improved	6	42.8	50	27.0
No improvement	-	-	-	-
Total	14	100	185	100

Subtitle: BAHA = Bone Anchored Hearing Aid; CI = Cochlear Implant

DISCUSSION

Auditory rehabilitation of individuals with unilateral hearing loss has been the object of study in the medical and speech-language classes due to the expansion of the criteria for indication of implantable hearing systems[33], however, there is still controversy about which type of implant is most appropriate, since some studies suggest BAHA and others, the CI.

The BAHA makes a contralateral stimulation, that is, the vibrator placed on the bad ear mastoid stimulates the best ear via bone conduction, assisting in the localization of the sound source and the auditory recognition[1]. The CI, instead, is implanted in the bad ear and will stimulate the nerve endings of this ear[10].

Based on this, it was sought for a review of the literature on the effects of BAHA and CI, specifically on two clinical outcomes: speech recognition in the presence of noise and sound localization.

After rigorous evaluation, 14 studies that addressed the outcome of improved speech recognition in the presence of noise were analyzed. All studies with CI and BAHA, except one, presented statistical data proving that speech recognition in the presence of noise improved after implantation. The article that did not report alteration[17] evaluated 11 subjects, ranging in age from 21 to 64 years and time of sensorial deprivation between one and 13 years. The results of the recognition tests were compared with those of the patients themselves (with and without BAHA) and with a normal hearing control group. The authors concluded that speech recognition improved in the group implanted with the BAHA, but when these same subjects were submitted to diffuse auditory stimulation with overlapping speech and noise, the results of normal hearing individuals were better. There is no record in the study whether patients underwent auditory training.

Recognize speech in the presence of noise is a challenge, even for normal hearing listeners. The auditory task ceases to be simple and requires special treatment by the brain, which must perceive the two sounds, focus attention on one (the target figure or sound) to the detriment of the other (noise or undesirable sound)[34]. Thus, in deaf patients who use some type of rehabilitation strategy, this ability must be trained in speech therapy that, thanks to neuroplasticity, has achieved good results[10].

With regard to the outcome of improving the sound source localization ability, 14 studies were analyzed. All CI studies presented statistical data proving that the sound localization improved after implantation. With the use of the BAHA, there are divergences: in five studies, the statistical analysis suggested that there was an improvement, and three did not. This fact explains why stimulating the contralateral side by bone vibration does not generate the binaural summation that occurs with bilateral hearing[35], necessary for the location of the source.

To accomplish the task of locating the source, the individual needs two functioning ears, which will, at the level of the lower brainstem, perform an analysis of interaural differences[4]. The studies seem to demonstrate that the CI generates this auditory activity.

During the analysis of the articles that composed this SR, it was possible to verify the great variability of data and the difficulty of working with the control group when the theme was auditory rehabilitation. Most research was self-controlled and the sample was intentional, generating qualitative statistical analysis, which made it impossible to perform the meta-analysis.

Meniere's disease is a set of symptoms that includes sensorineural hearing loss, episodic vertigo, tinnitus, and aural fullness. Its prevalence is low in the general population, but in the more advanced age groups, frequency increases, with a predominance of females and a greater number of bilateral impairments[36]. Nevertheless, in the articles of this SR, this disease predominated as the main reason for the unilateral hearing loss. The main causes reported in the studies were ototoxicity, meningitis, and rubella[37].

Regarding the period of hearing deprivation, there was

great variation in the studies[12,13,14,22,23,24], and, the longer the deprivation time, the greater the injury to the subject, since deprivation prevents neuroplasticity, which is the ability of the central nervous system to adapt, having the ability to modify its structural and functional organization[38]. Early intervention is important in hearing loss to minimize the deprivation losses[26,29].

Finally, it is necessary to comment on two data that made it difficult to perform the SR: 1) The heterogeneity of the investigated samples, regarding period of sensory deprivation, cause of deafness and speech-language rehabilitation modality, facts that interfered in the quality of the audiological results, after fitting; 2) The diversity of protocols and criteria for evaluating results.

These considerations, added to the constant technological evolution of hearing aids, regarding technology and connectivity, refer to the need to conduct clinical trials with greater scientific rigor, involving the thematic[33].

CONCLUSION

Despite the great clinical heterogeneity observed among the studies that evaluated the auditory rehabilitation of patients with unilateral hearing loss, it is possible to conclude that the cochlear implant provides better results, both for the localization of the sound source and speech recognition in the presence of noise.

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