Benefit and Quality of Life After Bone-Anchored Hearing Aid Fitting in Children With Unilateral or Bilateral Hearing Impairment

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Objective: To evaluate the benefits of a bone-anchored hearing aid (BAHA) in the daily lives of hearing-impaired children.

Design: Retrospective questionnaire study.

Setting: Nijmegen Medical Centre, Nijmegen, the Netherlands.

Patients: Thirty-eight BAHA users with a minimum age of 4 years at BAHA fitting and 1 to 4 years of use, divided into groups with bilateral conductive or mixed hearing loss and either normal cognition or mental disability and a group with unilateral conductive hearing loss.

Main Outcome Measures: Scores on the Glasgow Children’s Benefit Inventory, Abbreviated Profile of Hearing Aid Benefit, and Health Utilities Index Mark 3.

Results: The Glasgow Children’s Benefit Inventory showed a subjective overall benefit of +32, +16, and +26 in the 3 groups (on a scale of −100 to +100). The Abbreviated Profile of Hearing Aid Benefit also showed an overall mean benefit in the groups. On an individual level, a clinically significant benefit was reported by more children in the group with bilateral hearing loss and normal cognition (7 patients [70%]) than in the unilateral hearing loss group (4 patients [27%]). Overall mean health utility scores and disability index scores on the Health Utilities Index Mark 3 were comparable among the 3 groups.

Conclusion: Overall, BAHA fitting can be considered effective and beneficial in children with bilateral or unilateral hearing loss.


INCE ITS INTRODUCTION MORE than 30 years ago, the bone-anchored hearing aid (BAHA) has become an established treatment option for auditory rehabilitation in patients with chronic conductive or mixed hearing loss.1-3 When the BAHA was first introduced, it was mainly fitted in adults.4 In 1992, Jacobsson et al5 reported the use of the BAHA in children. This was followed by reports from other BAHA teams describing their clinical findings on the surgical and audiologic aspects of BAHA fitting in children.5-16 Gradually, the BAHA has been recognized as first-line therapy in children with bilateral conductive hearing loss (BHL) who are still too young to undergo microsurgery of the middle ear.3,17 Infants with hearing impairments can be fitted with the BAHA softband during their very early years of life.3,18 This facilitates hearing earlier in life, particularly in the bilaterally impaired. For unilaterally impaired children, this benefit is disputed. In children with congenital unilateral conductive hearing loss (UHL), the BAHA provides a valuable way of creating binaural hearing.3,17,20,21 For these subgroups, however, the audiologic outcome varies.

In addition to doing a clinical evaluation, some research groups have used non-validated questionnaires to gain insight into patient satisfaction regarding their day-to-day use of the BAHA.22-24 In such studies, quality of life (QOL) questionnaires are typically used as supplements to other research. More recently, the QOL and treatment benefits have been addressed by means of validated questionnaires in adults25 and children.11,21,26-29 In the pediatric population, these QOL studies have examined different causes and pathological processes of disorders. For example, studies have been conducted among children with diverse types of unilateral hearing impairment, both acquired and congenital21,26-28; bilateral acquired or congenital conductive hearing impairment27,28; and Down syndrome.27,30,31 In 2008, McDermott et al29 evaluated QOL in a cross-sectional study of children with UHL or BHL by using the Glasgow Children’s
Benefit Inventory (GCBI). They concluded that the BAHA significantly enhanced the general well-being of the children. It is essential, though, to obtain and analyze QOL data on the effects of the BAHA fitting for each type of hearing loss, particularly for unilaterally impaired children, in whom it is not yet clear how to predict treatment success. To the best of our knowledge, only 1 study (Priwin ef al21) has evaluated the subjective benefits and QOL in separate groups of children with BHL or UHL.

The ideal tool for evaluating the subjective effects of hearing aid fitting in day-to-day life should assess several aspects. First, it should assess the effect of the impairment on an individual’s auditory functioning in daily life and the benefit the person experiences with regard to his or her disability when using the hearing aid. Second, the tool should accurately evaluate the hearing aid’s contribution to the general quality of a patient’s day-to-day life. Third, the patient’s opinion about his or her general state of health (ie, QOL) should also be assessed.

To obtain reliable data in retrospective evaluations, recall bias should be minimized. To do so, the interval between the evaluation and the device fitting should not be too long. In contrast, it is important that the patient have had sufficient experience with the hearing device to give adequate responses and to minimize bias caused by initial enthusiasm. Recall bias and questionnaire completion can be managed by having the parents and the child fill out the questionnaires together.

To our knowledge, none of the questionnaires that were recently made available address the disability, handicap, benefit, and QOL simultaneously. Moreover, no study on BAHA use in children has addressed these items simultaneously. To address this lack of data, 3 well-known, validated questionnaires were used in this study. The aim of the study was to evaluate the effect of the BAHA on the day-to-day lives of children with UHL and BHL by means of validated questionnaires.

**METHODS**

**PATIENTS**

A total of 38 of 134 children fitted with a BAHA in Nijmegen, the Netherlands, were included in this study. The inclusion criteria were a minimum age of 4 years at BAHA fitting and 1 to 4 years of BAHA use. Parents were asked to fill out the questionnaires with their children to emphasize the opinion of the child.

To adequately evaluate the questionnaire results, the population was divided into 2 groups, those with BHL and those with UHL. Within the BHL group, subgroups of children with normal cognition (BHL-NC) and children with mental disability (BHL-MD) were defined because mental disability might influence patient outcomes. In the UHL group, all children had normal cognition and a congenital origin of their unilateral hearing loss. Audiologic data were also obtained.

**METHODS**

This retrospective questionnaire study used the following 4 tools: (1) a “daily device use” questionnaire (a nonvalidated questionnaire designed for this study to evaluate the BAHA in daily situations [Table 1]), (2) the GCBI,31 (3) the Abbreviated Pro-

file of Hearing Aid Benefit (APHAB),33 and (4) the Health Utili-
ties Index Mark 3 (HUI-3).34,35

The GCBI retrospectively measures the health-related quality of a child’s day-to-day life after an otorhinolaryngologic intervention, such as BAHA fitting. It is, therefore, considered to be a disease-specific QOL instrument. The questionnaire is composed of 24 questions that are divided into 4 domains: emotion, physical health, learning, and vitality. The GCBI outcome is quantified with a score between −100 and 0, which reflects a diminished QOL, and a score between 0 and +100, which reflects an improved QOL.

The APHAB assesses auditory functioning in daily life and is a hearing disability-specific questionnaire. A reduction in hearing disability achieved by fitting a hearing aid (in this case, a BAHA) is measured by 24 questions subdivided into 4 subscales: ease of communication (EC), reverberation (RV), background noise (BN), and aversiveness to sound. The APHAB has a scoring scale from 1 to 99, with a higher score indicating more frequent problems. The APHAB was completed twice by the study participants, with the first questionnaire based on the current situation and the second one based on the previous situation without the BAHA. To define clinical significance on an individual level for each subgroup, a difference of at least 22 points was considered to be statistically significant.36 An overall difference in the scores of more than 10 points for a given subgroup (ie, EC, RV, and BN) was also considered to be statistically significant.36 Data collected by Cox36 from a normative group of young controls with normal hearing were used for comparison.

The HUI-3 is a generic, multiattribute, preference-based instrument used to measure general health-related QOL. This is one of the few general QOL questionnaires that is able to capture changes in QOL as a result of hearing aid fitting.37-39 The HUI-3 consists of the following 8 subdomains: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain. In the HUI-3, there are 2 types of scores: the single-attribute utility and the multiattribute utility. The single-attribute utility score varies from 0 (highest degree of impairment or disability) to 1.00 (no impairment). The multiattribute utility score varies from −0.36 (most disabled) to 1.00 (perfect health), whereas 0 corresponds to death.35-41 In this study, the HUI-3 was used to provide a “snapshot” of the current health status of the subgroups. In addition, the HUI-3 can be used to assess a handicap index.35 This index has the following 4 categories: no disability (1.00), mild disability (0.89 to 0.99), moderate disability (0.70 to 0.88), and severe disability (<0.70).

**STATISTICAL ANALYSIS**

The unpaired, 2-tailed t test and the Kruskal-Wallis test were used to compare the mean values on the different domains of the GCBI to determine a difference between the benefits experienced by the BHL-NC group and the BHL-MD group. A P value of less than .05 was chosen as the level of significance, which corresponded to P = .025 for the 2-tailed t test. Correlations between demographic factors and the questionnaires and interquestionnaire correlations were tested with Spearman r. SPSS version 16 (SPSS, Inc, Chicago, Illinois) and Prism Graph Pad 5 (GraphPad Software, La Jolla, California) were used for analysis.

**RESULTS**

**PATIENTS**

The response rate to the questionnaires was 82% (31 of 38 children). Nonresponders (n=7) were contacted by
Mean age at implantation was 7 years (range, 4-16 years). Age at the time of the questionnaire was 10 years (6-17 years). Eighteen patients (58%) were male and 13 (42%) were female. Descriptions of the subgroups (BHL-NC, BHL-MD, and UHL) are given in Table 2.

### Table 1. Daily Use Questionnaire Responses

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
<th>Group, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you still using your BAHA?</td>
<td>Yes</td>
<td>BHL-NC (n=10)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BHL-MD (n=6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UHL (n=15)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>During the past 2 wk, how many hours a day did you use your BAHA on average?</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&lt;1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1-4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>4-8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&gt;8</td>
<td>9</td>
</tr>
<tr>
<td>Do you consider your BAHA to be worth the effort?</td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>A little</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Moderately</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Much</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Very much</td>
<td>6</td>
</tr>
<tr>
<td>Do you find it difficult to place your BAHA?</td>
<td>Yes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>10 (100)</td>
</tr>
<tr>
<td>Can you handle your BAHA well?</td>
<td>Yes</td>
<td>10 (100)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0</td>
</tr>
<tr>
<td>Are you familiar with the extra options on your BAHA (for example, the audio connection)?</td>
<td>Yes</td>
<td>2 (20)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>8 (80)</td>
</tr>
<tr>
<td>Do you find it difficult to clean the skin around the implant?</td>
<td>Yes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>2 (20)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>7 (70)</td>
</tr>
<tr>
<td>What do you think about the quality of sound from your BAHA?</td>
<td>Good</td>
<td>6 (60)</td>
</tr>
<tr>
<td></td>
<td>Reasonable</td>
<td>2 (20)</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Very poor</td>
<td>0</td>
</tr>
<tr>
<td>Would you recommend the BAHA to a friend with the same type of deafness?</td>
<td>Yes</td>
<td>9 (90)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>1 (10)</td>
</tr>
<tr>
<td>Would you (parent/caregiver) be prepared to pay (&gt;€3000) yourself to have your child fitted with a BAHA?</td>
<td>Yes</td>
<td>7 (70)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>2 (20)</td>
</tr>
</tbody>
</table>

**Abbreviations**: BAHA, bone-anchored hearing aid; BHL, bilateral conductive hearing loss; MD, mental disability; NC, normal cognition; UHL, unilateral conductive hearing loss.

a Some individuals in the BHL-NC and BHL-MD groups did not answer all the questions.

### Table 2. Descriptive Population Data

<table>
<thead>
<tr>
<th>Group</th>
<th>BHL-NC (n = 10)</th>
<th>BHL-MD (n = 6)</th>
<th>UHL (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congenital origin of hearing loss, No. (%)</td>
<td>8 (80)</td>
<td>2 (33)</td>
<td>15 (100)</td>
</tr>
<tr>
<td>Age at implantation, mean (range), y</td>
<td>7 (5-13)</td>
<td>11 (4-16)</td>
<td>7 (4-12)</td>
</tr>
<tr>
<td>Age at questionnaire, mean (range), y</td>
<td>10 (6-15)</td>
<td>12 (6-17)</td>
<td>9 (5-16)</td>
</tr>
<tr>
<td>Bilateral BAHA users, No. (%)</td>
<td>5 (50)</td>
<td>3 (50)</td>
<td>NA</td>
</tr>
<tr>
<td>Conventional bone conductor use before BAHA, No. (%)</td>
<td>5 (50)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>PTAbc, mean (SD), dB HL</td>
<td>4 (8)</td>
<td>23 (9)</td>
<td>10 (10)</td>
</tr>
<tr>
<td>PTAac, mean (SD), dB HL</td>
<td>49 (11)</td>
<td>61 (15)</td>
<td>56 (17)</td>
</tr>
<tr>
<td>Air-bone gap, mean (SD), dB HL</td>
<td>45 (15)</td>
<td>34 (13)</td>
<td>46 (14)</td>
</tr>
<tr>
<td>Type of mental disability, No. (%)</td>
<td>Down syndrome</td>
<td>NA</td>
<td>3 (50)</td>
</tr>
<tr>
<td></td>
<td>De Grouchy syndrome</td>
<td>NA</td>
<td>1 (17)</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>NA</td>
<td>2 (33)</td>
</tr>
</tbody>
</table>

**Abbreviations**: ac, air conduction; BAHA, bone-anchored hearing aid; bc, bone conduction; BHL, bilateral conductive hearing loss; HL, hearing level; MD, mental disability; NA, not applicable; NC, normal cognition; PTA, pure-tone average; UHL, unilateral conductive hearing loss.
BHL GROUP

A total of 16 children responded to the questionnaire: 10 in the BHL-NC group and 6 in the BHL-MD group.

Daily Device Use Questionnaire Responses

In the BHL-NC group, 9 children (90%) were using the BAHA for more than 8 hours a day (Figure 1). Most children in this group (8 [80%]) reported that the BAHA was worth the effort (Figure 2). There were no reports of problems with placement or handling of the BAHA, and only 2 of 9 children (22%) experienced occasional problems with cleaning around the implant (Figure 3). See Table 1 for more details. In the BHL-MD group (n=6), the answers were more varied (Table 1).

GCBI Responses

An overview of the GCBI scores is given in Table 3 and Figure 4. In the BHL-NC group, 8 children reported benefits from using the BAHA. However, 2 children (20%) were having problems in at least 1 of the subdomains. The BHL-MD group had lower overall scores on the GCBI. Three children had negative scores on the GCBI.

Although the overall mean scores of the BHL-MD group were lower than those of the BHL-NC group, there were no significant differences between these groups for any of the subdomain scores.

APHAB Responses

To determine the amount of benefit derived from using the BAHA, the patients were asked to fill out the APHAB retrospectively, thereby taking their situation before BAHA fitting into account. A dotted line at the 10-point level and the norm scores are shown in Figure 5. The mean group scores on subdomains EC, RV, and BN were all above the 10-point level. Individual data, however, showed that 7 patients (70%) experienced a significant overall clinical benefit. None of the patients reported a clinically significant deterioration in their hearing when using the BAHA. Four of these 7 patients had not been using a hearing aid previously, and 3 of them had used a conventional bone conductor. No differences were seen between these 2 groups.

Only 3 of 6 caregivers for the children in the BHL-MD group responded to the APHAB questionnaire. One of them remarked that the questions were too difficult for the child to answer. Therefore, all the APHAB data from this group were excluded.

HUI-3 Responses

The scores on each of the 8 subdomains are presented in Table 3. In the BHL-NC group, the mean (SD) scores ranged from 0.80 (0.10) to 1.00 (0.00). The overall mean utility score was 0.83 (0.14). The disability scale categorized patients as having no disability (n=1 [10%]), mild disability (n=2 [20%]), moderate disability (n=6 [60%]), or severe disability (n=1 [10%]).

In the BHL-MD group, the mean scores were considerably lower, ranging from 0.54 (0.14) to 1.00 (0.04), with
The lower scores were mostly due to comorbid conditions and lower scores for dexterity, speech, and cognition. In this group, all children were classified as having severe disability on the disability scale.

Findings Across Questionnaires

Within the BHL-NC group, there were no differences in the GCBI, APHAB, and HUI-3 scores between the following groups: unilateral BAHA users and bilateral BAHA users; BAHA users with congenital causes and those with acquired causes; and those who previously used conventional hearing aids and those who did not. A negative correlation was found between the age at BAHA fitting and scores on the GCBI, which indicated that the younger the child was at the time of BAHA fitting, the greater the benefit that could be experienced ($r = -0.68$, $P = .02$).

There were no interquestionnaire correlations between the domains or subdomains of the questionnaires used. However, a trend was seen between the learning subdomain of the GCBI and the BN subdomain of the APHAB ($r = 0.6$, $P = .06$).

UHL GROUP

Daily Device Use Questionnaire Responses

In the UHL group (n=15), 7 children (47%) were using their BAHA devices for more than 8 hours a day, and 6 children (40%) were using them for 4 to 8 hours a day (Table 1, Figure 1). The BAHA was considered to be either
worth the effort or very much worth the effort by 10 (67%) of the patients surveyed (Table 1, Figure 2).

GCBI Responses

An overview of the GCBI scores is given in Table 3 and Figure 4. The results were comparable with those found in the BHL-NC group, although 3 children (20%) reported problems in at least 1 of the subdomains.

APHAB Responses

Only 4 children (27%) experienced a significant overall benefit (scores of 10+ for each subdomain) from using the BAHA, according to the results of the APHAB. Significant deterioration did not occur. A significant benefit was seen in 4 children (27%) for subdomain EC, 7 children (47%) for RV, and 8 children (53%) for BN. The age at the BAHA fitting was negatively correlated with children (47%) for RV, and 8 children (53%) for BN. The significant correlation with age was fitted at an early age. None of the other subdomains showed significant correlations with age.

HUI-3 Responses

The mean (SD) scores on the HUI-3 subdomains ranged from 0.85 (0.11) to 1.00 (0.0). The overall mean utility score was 0.82 (0.12). The disability scale categorized patients as having no disability (n=2 [13%]), mild disability (n=3 [20%]), moderate disability (n=8 [53%]), or severe disability (n=2 [13%]).

Findings Across Questionnaires

The learning GCBI subdomain showed a statistically significant correlation with the APHAB benefit of BN (p=0.53, P=.04).

The unaided APHAB RV subdomain score was positively correlated with the overall subdomain (p=0.71, P=.003), the emotion subdomain (p=0.66, P=.008), the learning subdomain (p=0.54, P=.04), and the vitality subdomain (p=0.53, P=.04). This suggests that patients, especially those experiencing problems hearing in large rooms (eg, lecture halls, theaters, or classrooms) because of reverberation, might experience some benefit from use of the BAHA.

Figure 5. Mean (SD) benefit scores on the Abbreviated Profile of Hearing Aid Benefit (APHAB) subdomains ease of communication (EC), reverberation (RV), background noise (BN), and aversiveness to sound (AV). BHL indicates bilateral conductive hearing loss; NC, normal cognition; and UHL, unilateral conductive hearing loss. There was significant benefit for the majority of the children in the BHL-NC group (scores above the 10-point line). In the UHL group, a significant benefit was seen for BN on a subdomain-specific level (majority of scores above the 22-point line).

least 1 year. To complete the retrospective questionnaires, parents and children had to recall their situation before the BAHA was fitted, which was as long as 4 years ago. This may have posed a limitation for the study; however, the choice of 4 years as the upper limit for duration of the BAHA allowed for a study population large enough to sufficiently evaluate the level of benefit. The parents were asked to answer the questions based on the child’s opinion as much as possible. All parents stated that they could sufficiently recall their child’s situation before the BAHA was fitted. Therefore, the answers were considered to be reliable. The minimum age for inclusion in the study was 4 years, the age at which Dutch children go to nursery school, where their abilities are tested more completely than at younger ages.

In this study population, there were 6 children with mental disabilities. The literature shows that patients with disabilities do indeed derive benefit from the BAHA. However, to evaluate this specific patient group, their findings need to be analyzed separately. Three of the 6 parents were unable to respond to the APHAB on behalf of their child. As a result, the APHAB was determined to be too difficult to use in this population and the data from the APHAB were excluded for this group.

It was not possible to draw any firm conclusions regarding comparisons of the BHL-NC and the BHL-MD groups because the number of participants was too small. Nevertheless, some of the children in the BHL-MD group derived more benefit from the BAHA than the previous device, whereas others did not. The very low scores on the HUI-3 could be explained by comorbidities related to mental disability and/or physical handicap. Overall,
the study population was relatively small and, therefore, more research on this specific BAHA population is needed to draw more firm conclusions.

**BHL GROUP**

The BAHA is considered to be the best option for children with BHL (our BHL-NC group) (consensus statements, Snik et al). In general, these children derive a great benefit from the BAHA in everyday situations. Our findings support those of other publications on the use of the BAHA in pediatric populations.

Overall, the GCBI showed a general benefit of BAHA use in the BHL-NC group. There was a particularly large benefit on the learning subdomain, which underscores the impact of the BAHA on hearing-impaired children’s education. High scores were also seen for the emotion subdomain, which is an encouraging finding for a child’s development.

We found that a younger age at the time of BAHA fitting correlated with higher scores on the GCBI, which emphasizes the need for early hearing aid fitting in children with BHL.

**Figure 6** shows the scores from all children who participated (n=31) compared with findings reported in the recently published literature. In a retrospective study, McDermott et al evaluated data from 84 children who had been fitted with a BAHA during a period of 15 years. The GCBI scores for all subdomains reported in their study were significantly higher than the scores reported herein (P<.01). One explanation for this discrepancy may be the differences in the study populations. In our study, about 19% of study participants had syndromic features compared with 48% in the population studied by McDermott et al. Their approach to these patients, who require additional treatment for their particular comorbidities, involved an integrated program of evaluation and rehabilitation. It is possible that this program created additional subjective treatment benefit for these patients, which was reflected in the scores on the GCBI.

Mean scores on the APHAB showed a significant treatment benefit in most children in the BHL-NC group (Figure 5, Table 3). The scores on the subdomains EC, RV, and BN all fell around the 80th percentile line for normal-hearing subjects, which indicates that 80% of the normative group with normal hearing experienced fewer problems in these listening conditions than the current population (Figure 7). These findings emphasize that, although the BAHA provides benefit in the majority of cases, there is still residual disability compared with normal-hearing children.

In the BHL-NC group, the HUI-3 results also support the fact that there is still a residual disability when the BAHA is used. In the current study, the overall mean multiattribute utility score on the HUI-3 was 0.83 (0.14), which correlates with a moderate disability score. Table 3 shows that a large part of the deviation from perfect health in preference scores can be attributed to the hearing and speech domains, which is not surprising because speech relies heavily on auditory input. The HUI-3 score in the BHL-NC group indicated a comparable QOL compared with previous reports in the literature.

The results found in children with BHL show an interquestionnaire trend between the benefit of the BAHA in listening conditions with background noise and the beneficial effect of the BAHA on learning capabilities (P=0.6, P=.06). Thus, the beneficial effects of BAHA use, especially in noisy environments, may also explain its positive effect on learning in these children.

**UHL GROUP**

According to the consensus statements, the BAHA is also an important treatment option for children with UHL. However, the predictor for success is still unclear in this group. Kunst et al studied 10 children and 10 adults with UHL. The BAHA had a beneficial effect on speech
recognition in a noisy environment in a setup with spatially separated speech and noise sources, although this result could be attributed to effectively lifting the acoustic head shadow.

Priwin et al\textsuperscript{21} did not find any benefit from the BAHA during directional hearing tests in a group of 6 children with congenital UHL. In some cases, directional hearing even deteriorated when the BAHA was used.

Overall, there is no clear evidence to date that a BAHA is beneficial to all children with UHL.\textsuperscript{17} To gain more insight into the mechanisms of how patients derive benefit from the BAHA in this patient group, we evaluated the subjective measurements of the BAHA in 15 children with congenital UHL. On the daily device use questionnaire, the UHL group reported that the BAHA was worth the effort in general. However, they did not seem to be using the BAHA all day, and they were not overly impressed by the sound quality. Furthermore, only 67% of the children with UHL would recommend the BAHA to peers compared with 90% in the BHL group. Some of the patients with UHL responded that they used the BAHA only in the classroom, which has also been reported in other studies.\textsuperscript{21} The BAHA has proved to be particularly beneficial in speech recognition tests in the setting of noise in patients with UHL. Therefore, the BAHA might be particularly beneficial in the school environment for these children, which is the most important time of the day.\textsuperscript{17,21,46,47}

In this study, children with UHL and a BAHA showed a similar benefit, as measured by the GCBI, as the children with BHL and a BAHA. However, 3 of 15 children in the UHL group had a negative score on 1 of the subdomains. These disappointing results emphasize the importance of performing a trial with a headband to predict which children will benefit most from a BAHA in different listening conditions, including both at home and in school. Previously, Kunst et al\textsuperscript{26} used the GCBI to study 10 children with UHL recruited from this clinic. The scores for the subdomains were comparable to those from our study (Figure 8).

On the basis of the fact that the study subjects scored highest on the learning subdomain, it can be concluded that, in children with a unilateral air-bone gap, the BAHA is particularly beneficial in educational settings. Only 4 patients in the UHL group (27%) derived a significant benefit overall from the BAHA, according to the APHAB assessment made with the criteria defined by Cox.\textsuperscript{36} Their poor results could be attributed to a low score of 27% on the EC subdomain compared with 47% and 53% on both the RV and the BN subdomains. These findings indicate that the BAHA does not lead to a significant benefit in all domains assessed by the APHAB in children with UHL. Hypothetically, patients with a congenital, unilateral air-bone gap use their normal contralateral ear to compensate for their impaired ear, which would undermine the benefit of the BAHA. The relatively positive results seen in the subdomains RV and BN might be due to the synergistic effect of binaural hearing and lifting the head shadow, respectively.

The results of the APHAB reiterate that it is of the utmost importance for children with UHL to undergo a trial period with the BAHA on a headband or softband to establish whether the BAHA will provide optimal treatment. The HUI-3 and disability scores in the UHL group were comparable to the scores in the BHL-NC group. For this population, therefore, the BAHA has a beneficial effect, although a residual moderate disability remains. It is difficult to assess the benefit of a BAHA in this population; therefore, a preoperative screening for disability conducted in reverberated rooms with the use of the APHAB might be a valuable way to assess potential additional benefits.

This study further supports the finding that the BAHA is beneficial for children with BHL. Children with normal cognition and those with mental disability gave positive subjective reports about the BAHA. Subjective evaluations by the children with UHL were more varied than those by the children with BHL. In children with UHL, the decision to use a BAHA should be made on an individual basis with the aid of a trial period of at least 2 weeks, which allows the child to use the BAHA in a variety of settings, particularly in a school environment. Overall, the BAHA was particularly beneficial for a child’s learning, which may be largely due to its beneficial effects in noisy surroundings.

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