

**Bilateral Cochlear Implantation
Selected Bibliography of Peer-Reviewed Publications**

Study/Date/ Design	Participants	Objectives	Outcomes Measured	Results	Conclusions
BILATERAL IMPLANTATION IN CHILDREN (alphabetical by author)					
<p>Kuhn-Inacker H, et al. Bilateral cochlear implants: a way to optimize auditory perception abilities in deaf children? Intl J Pediatr Otorhinolaryngol 2004;68:1257-1266. Cohort study</p>	<p>39 bilaterally implanted children, heterogeneous with regard to age at first and second implantation, time lag between implants and onset of hearing loss. Children</p>	<p>Evaluate auditory skills of the children based on free observation. 18 children tested for speech discrimination in noise.</p>	<ul style="list-style-type: none"> • Speech audiometry (in quiet) with both CIs on, as well as with each CI (right and left) separately. • Speech discrimination in noise. 	<ul style="list-style-type: none"> • Mean word discrimination scores with both CIs (86.4%) higher than scores with left (75.1%) or right CI alone (71.8%). • Difference between the bilateral condition and best unilateral condition was statistically significant ($p < 0.05$). • All children except the youngest achieved speech discrimination in noise for bisyllabic words in open-set format. Open-set speech scores ranged from 46 -100% bilaterally, 21-78% unilaterally. • Mean difference in bilateral vs. unilateral speech discrimination scores was 18.4 percentage points ± 8.2 ($p < 0.001$). 	<p>Bilateral CI improves children's communication, especially in complex listening situations. Integration of second implant and use of binaural information was easier and faster in children with a short time lag between implants. Intensive rehabilitation is necessary to obtain optimal benefit from bilateral CI. Age at implantation and time lag between implants affect the intensity of training needs.</p>
<p>Litovsky RY, et al. Benefits of bilateral cochlear implants and/or hearing aids in children. Int J Audiol 2006;45 (Suppl):78-91. Comparative cohort study</p>	<p>Two groups: 10 children ages 3-14 when tested who received bilateral CIs at least 1 yr apart. 10 children ages 6-14 when tested, w/ hearing loss identified by age 2, unilaterally implanted between 1.5 and 8.5 yrs, hearing aid (HA) in other ear. Children</p>	<p>Evaluate potential benefits of bilateral and bimodal fittings, within each group and across groups, by comparing performance on speech intelligibility in quiet and in presence of competing speech signals.</p>	<p>Speech intelligibility (CRISP test) Minimum audible angle (MAA)</p>	<ul style="list-style-type: none"> • MAA measures suggest that bilateral listening modes are significantly more beneficial for children with bilateral CIs than children with bimodal (CI-HA) hearing (all CI-CI children showed some binaural effect). • Children with bilateral CIs and CI/HA performed similarly on word ID, either in quiet or in presence of competing sounds. • Great variability in measured SRTs, ranging from normal to substantially below normal. • Age effect may also have occurred; the two 6-year-olds generally had higher SRTs than the older children. 	<p>Bilateral stimulation w/ either 2 CIs or CI/HA improves performance on measures of bilateral advantages. Children with two CIs performed significantly better than children with CI/HA on 2 measures: (1) speech intelligibility w/ 2 devices vs. one and (2) advantage gained from bilateral devices on minimum audible angle (localization acuity) task. The ability to benefit from two CIs does not require prior binaural hearing experience.</p>
<p>NOTES: Excludes case reports with fewer than 3 subjects, abstracts of unpublished research, and technical papers without patient outcomes.</p>					

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<p>Litovsky RY, et al. Bilateral cochlear implants in children: localization acuity measured with minimum audible angle. <i>Ear Hear</i> 2006;27:43-59.</p> <p>Comparative cohort study</p>	<p>Two groups of children: 13 with BI CI, age 3-16, six with a hearing aid in nonimplanted ear, ages 4-14; all but one with severe pre-lingual hearing loss.</p> <p>Children</p>	<p>Evaluate sound localization acuity in children who received bilateral CI in sequential procedures.</p> <p>Determine extent to which BI CI affects sound localization acuity.</p> <p>Investigate extent to which hearing aid in nonimplanted ear can improve sound localization.</p>	<p>Ability to discriminate sounds presented to the right or left.</p> <p>MAA thresholds in the BI listening mode and under monaural conditions.</p>	<ul style="list-style-type: none"> • 69% (9/13) of children in bilateral CI group discriminated left/right for source separations of <20°, and of those, 77% (7/9) performed better when listening bilaterally. • Several children also performed test w/ single CI under some conditions. MAA thresholds better in first CI than second CI listening mode for nearly all (8/9) subjects. • Children followed over 2 yrs improved with increased auditory experience. • Children with HA in nonimplanted ear could sometimes perform task. Average group performance was worse than that of the children with bilateral CI when both ears were activated but not significantly different when listening with a single CI. 	<p>Many but not all children with sequential bilateral CI perform better on measures of localization acuity with two CIs compared with one and are better at the task than children with one CI and a hearing aid.</p> <p>Additional investigation required regarding critical period for implantation and measures of fused or correlated signals.</p>
<p>Peters BR, et al.</p> <p>Importance of age and post-implantation experience on speech performance in children with sequential bilateral cochlear implants. <i>Otol Neurol</i> 2006 (in press).</p> <p>Multi-center repeated measures cohort study</p>	<p>30 children, ages 3 to 13, who received 1st implant before age 5, acquired language ability, and had 2nd implant at various ages.</p> <p>Children</p>	<ul style="list-style-type: none"> • Evaluate effect of patient age at 2nd implant on ultimate hearing w/ that ear. • Determine if 2nd CI affects speech perception ability with that ear alone. • Determine existence of bilateral benefit even if second ear does not perform as well as first. 	<p>Performance on speech perception testing in quiet and noise pre-operatively and post-activation at 3, 6, and 12 months (+ 24 months for older children) in unilateral and bilateral conditions.</p>	<ul style="list-style-type: none"> • Children implanted sequentially have speech perception in 2nd ear w/in 6 mos. • Children < age 8 acquire speech perception faster and ultimately reach higher level of understanding. • Speech intelligibility in noise was significantly better bilaterally than w/ either ear alone. • Bilateral benefit increased over time. 	<p>Sequential bilateral CI in children can improve speech perception in quiet and noise.</p> <p>Improvement continues for 12 months post-activation of 2nd implant; scores inversely related to age at 2nd implantation.</p> <p>Younger children achieve better speech discrimination ability, but all age groups show binaural gains.</p>

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BILATERAL IMPLANTATION IN ADULTS/ADOLESCENTS (alphabetical by author)					
<p>Au DK, et al.</p> <p>Superiority of bilateral cochlear implantation over unilateral cochlear implantation in tone discrimination in Chinese patients. <i>Am J Otolaryngol</i> 2003;24:19-23.</p> <p>Case series</p>	<p>4 postlingually deafened Cantonese-speaking adults (2 men and 2 women, ages 23-38) with bilateral MED-EL Tempo + CIs (3 sequentially, 1 simultaneously).</p> <p>Adults</p>	<p>Evaluate benefits of bilateral versus unilateral CIs.</p>	<p>Ability to discriminate Cantonese lexical tones in quiet and in noise.</p>	<ul style="list-style-type: none"> In quiet, scores in binaural and monaural hearing conditions were no different. At SNRs of +15, +10, and +5, subjects listening binaurally could achieve Cantonese lexical tones discrimination scores comparable to those obtained in quiet. In the unilateral mode, only at SNRs of +15 and +10 could subjects attain similar scores as those obtained in quiet. 	<p>Bilateral CIs resulted in better performance in discriminating Cantonese lexical tones from background noise compared with monaural hearing from unilateral CIs.</p>
<p>Dunn CC, et al.</p> <p>Effects of converting bilateral cochlear implant subjects to a strategy with increased rate and number of channels. <i>Ann of Oto Rhinol Laryngol</i> 2006. 115: 425-432.</p> <p>Repeated measures cohort study with historical comparison</p>	<p>7 adult bilateral Clarion CII recipients who had used CIS for ≥ 18 months, ages 28-69.</p>	<p>Evaluate speech perception for 3 Advanced Bionics processing strategies: 8-channel, 813 pps with CIS; 16-channel, 5100 pps HiRes Paired; 16-channel, 2900 pps, HiRes Sequential.</p> <p>Subjects alternated HiRes P and HiRes S daily for 1 month.</p>	<p>Multi-talker speech babble noise with CUNY sentences, noise from front.</p>	<ul style="list-style-type: none"> Bilateral HiRes scores on sentences in noise improved by 30-60% in one month for 6 subjects ($p < 0.001$) compared to CIS; unilateral HiRes users in Koch study improved only 14% over CIS (<i>Audiol Neurotol</i> 2004). For CIS after 6-18 months use of HiRes: 5 subjects still using Hi Res showed significant improvement vs. 2nd CIS measurement; 2 showed better CIS after HiRes vs. baseline CIS and 2 showed worse; ANOVA showed no significant differences due to small sample size. Immediate crossover: no statistical difference ($p > 0.05$) between mean CIS and HiRes but 5 subjects had 10 – 20% improvement. One month HiRes P vs. HiRes S: no significant difference; HiRes P was nominally better. One month HiRes vs. 3- to 6-month HiRes: no significant difference; 5 had no difference, 2 had decrements. 	<p>Dramatic improvement in speech perception in noise with HiRes 1 month after conversion from CIS. Improvement maintained at 3 months; 4 out of 5 maintained improvement at 6+ months.</p> <p>No difference between HiRes strategies.</p> <p>Improvement in sentence recognition scores was 30 – 60%, compared with prior study findings of 14% for unilateral HiRes (Koch, Osberger et al., <i>Audiol Neurotol</i> 2004).</p> <p>Further work needed to determine independent effects of rate vs. number of channels.</p>

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<p>Gantz BJ, et al. Binaural cochlear implants placed during the same operation. <i>Otol Neurotol</i> 2002;23(2):169-80. Single center cohort study</p>	<p>10 postlingually deafened patients (ages 35-75, duration of deafness 1 mo-37 yrs) with SNR differences between two ears, undergoing simultaneous bilateral implantation of the Cochlear CI24M at a tertiary referral center. Adults</p>	<p>Evaluate binaural listening advantages for speech in quiet and noise and for sound localization when independently programmed binaural CIs are used. Determine whether ears with different hearing ability and profound deafness duration perform differently with CIs.</p>	<p>Speech perception and localization in quiet and noise tested at 3 months and 1 year post-operatively. All testing was performed with right, left, and both CIs.</p>	<ul style="list-style-type: none"> • Sound localization improved with binaural implants in all subjects. • All subjects benefited from head shadow effect with ear with a better SNR. • At 1 year, 2 of 10 subjects showed a binaural advantage for speech testing in quiet, and 2 of 10 for speech-in-noise testing. • Pre-implant psychophysical or physiologic measures did not predict eventual speech perception performance. 	<p>Binaural CIs can assist in the localization of sounds and may improve speech understanding in quiet and in noise. Individuals with long periods of deafness obtained significant benefit. All subjects preferred using 2 implants. OR time only slightly longer than for single implant; patient recovery no different.</p>
<p>Laszig R, et al. Benefits of bilateral electrical stimulation with the Nucleus cochlear implant in adults: 6-month postoperative results. <i>Otol Neurotol</i> 2004;25:958-68. Multicenter repeated measures cohort study</p>	<p>37 profoundly deaf adults with bilateral CIs, 15 sequentially and 22 simultaneously implanted with Nucleus 24 and using Nucleus SPrint or ESPril 3G speech processor. Adults</p>	<p>Evaluate benefits of bilateral electrical stimulation for hearing-impaired adults using Nucleus 24 CI. Compare and quantify performance on speech perception measures in quiet and in noise and localization ability for unilateral and bilateral cochlear implant use.</p>	<p>Repeated single subject measures for each subject, with each subject serving as his or her own control. Assessment of unilateral and bilateral listening conditions for performance on tests of speech comprehension and sound localization were performed.</p>	<ul style="list-style-type: none"> • There was a statistically significant 8% improvement for bilateral listening compared with scores for better ear alone. • For spatially separated speech in noise, there was a consistent interaural performance advantage for the ear closest to the speech source whether or not the better ear was closest to the speech signal (head shadow benefit). • Bilateral stimulation always provided superior performance than unilateral listening with either ear when ipsilateral to the noise source. 	<p>Bilateral implants assist the hearing-impaired listener with communication in everyday listening both in noise and in quiet. Bilateral electrical stimulation improves speech comprehension and localization over unilateral listening conditions. This results from the combined effects of binaural head-shadow benefit and binaural auditory processing such as binaural redundancy and binaural squelch effects. These improvements combine to lead to improved speech comprehension and localization over unilateral listening conditions.</p>

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<p>Litovsky RY, et al. Bilateral cochlear implants in adults and children. Arch Otolaryngol Head Neck Surg 2004;130:648-55. Cohort study</p>	<p>20 subjects (17 adults, 3 children) were tested 3 months after bilateral activation. Adults received CIs in simultaneous procedures, children in sequential procedures (3-8 years apart). Children and adults</p>	<p>Measure the benefit of bilateral CIs in adults and in children.</p>	<p>Sound localization and speech intelligibility in noise (adults). Sound localization, right/left discrimination, speech intelligibility in noise (children).</p>	<p>Preliminary (3 month) findings</p> <ul style="list-style-type: none"> • Adults: bilateral hearing leads to better localization performance and speech intelligibility when the noise is near the poorer of the 2 ears. • Children: localization and discrimination slightly better under bilateral conditions. On the speech tasks, two children showed consistent improvement with bilateral hearing when the noise was near the earlier-implanted side; 1 child did not benefit . 	<p>Bilateral CIs may offer advantages to some listeners. Tasks used in this study may be useful for measuring such advantages, especially in young children. Extent of bilateral advantage difficult to ascertain after only 3 months; longer period of adjustment and learning required. Future work should address extent to which synchronization and enhanced binaural hearing are functionally useful to bilateral CI users.</p>
<p>Muller J, et al. Speech understanding in quiet and noise in bilateral users of the MED-EL COMBI 40/40+ cochlear implant system. Ear Hear 2002;23:198-206. Cohort study</p>	<p>9 adults with bilateral MED-EL 40/40+ implants. Adults</p>	<p>Investigate speech understanding in quiet and noise in subjects bilaterally implanted with multi-channel CIs.</p>	<p>Subjects tested on monosyllables in quiet and sentences in noise (10 dB SNR) under 3 conditions: with both implants, right implant only, and left implant only.</p>	<ul style="list-style-type: none"> • All subjects had higher speech scores with bilateral than with unilateral stimulation. • Average sentence understanding score was 31.1% higher with both CIs compared with CI ipsilateral to the noise, and 10.7% higher with both CI compared with the CI contralateral to the noise ($p < 0.05$ for both). • Average monosyllabic word recognition score was 18.7% higher with both CI than with one CI ($p < 0.05$). 	<p>Bilateral CI allows significantly better speech understanding in both quiet and noise. Lack of findings on squelch effect in other studies may be due to test conditions or ceiling effect. Better bilateral results in recent studies may be due to modern high-rate devices and coding strategies. Duration of deafness does not seem to be a contraindication for bilateral implantation.</p>

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<p>Nopp P, et al.</p> <p>Sound localization in bilateral users of MED-EL COMBI 40/40+ cochlear implants. Ear Hear 2004;25:205-14.</p> <p>Cohort study</p>	<p>20 hearing-impaired adults (19 post-lingually deafened), ages 17-67, mean 45; bilaterally implanted with MED-EL COMBI 40 or COMBI 40+ during adolescence or later. All used HA to various degrees pre-CI.</p> <p>Adults</p>	<p>Investigate sound localization with bilateral and unilateral CIs.</p>	<p>Sound localization was tested in the frontal horizontal plane by using 9 equally spaced loudspeakers and speech-shaped noise bursts at randomized levels. Subjects were asked to identify the speaker from which noise came.</p>	<ul style="list-style-type: none"> • Bilateral implants had substantial and significant benefit. All but 2 subjects substantially improved their sound localization ability when using both implants instead of one. • With bilateral CIs, average accuracy with which subjects could localize sounds improved by more than 30°. • Decreased variability ($>16^\circ$) of responses also indicates more consistent judgments with bilateral CIs. 	<p>Bilateral CIs offer substantial sound localization benefit to late-deafened, late-implanted subjects.</p> <p>For adults, a long duration of unilateral implant use seems to be no contraindication to bilateral cochlear implantation.</p> <p>Early implantation for early-deafened subjects might allow better acquisition of spatial hearing and lead to improved localization performance.</p>
<p>Ramsden R, et al.</p> <p>Evaluation of bilaterally implanted adult subjects with the Nucleus 24 cochlear implant system. Otol Neurotol 2005; 26(5):988-98.</p> <p>Multi-center repeated measures cohort study</p>	<p>30 adult CI users randomly recruited from 7 centers (ages 29 to 82, mean 57) who received 2nd implant 1-7 years (mean 3 yrs) after first device.</p> <p>Adults</p>	<p>Evaluate speech perception benefits of bilateral implantation for subjects who already have one implant.</p>	<p>Speech perception on standard tests in quiet and noise at 1 week, 3 months, and 9 months post-activation.</p>	<ul style="list-style-type: none"> • At 9 months, results showed a significant binaural advantage of $12.6 \pm 5.4\%$ ($p < 0.001$) over the first ear alone for speech and noise from the front ; a $21 \pm 6\%$ ($p < 0.001$) binaural advantage over the first ear alone when noise was ipsilateral to the first ear; 2nd ear in noise was $13.9 \pm 5.9\%$ worse than the first ear; no binaural advantage when noise was contralateral to the first ear. • 27/30 patients preferred sound quality with two CIs and used them both all day. 	<p>There is significant bilateral advantage of adding 2nd CI for this group. Sequential implantation with long delays between ears resulted in poor 2nd ear performance for some subjects and limited bilateral benefit for these users. The dual microphone does not provide equivalent benefit to bilateral implants.</p>
<p>Schleich P, et al.</p> <p>Head shadow, squelch, and summation effects in bilateral users of the MED-EL COMBI 40/40+ cochlear implant. Ear Hear 2004;25):197-204.</p> <p>Cohort study</p>	<p>21 adults (20 postlingually deafened) ages 17-66. Duration of deafness 0.6-47.8 yrs.</p> <p>Adults</p>	<p>Assess everyday speech perception by testing impact of bilateral CI use on speech perception in noise in bilateral CI users.</p>	<p>Speech perception under 3 different listening conditions: left CI, right CI, and both CIs. Sequence of measurement conditions (noise and listening conditions) and test lists was quasi-randomized.</p>	<ul style="list-style-type: none"> • Significant improvement was observed in all listening conditions but one (the squelch effect for noise from the right side, probably due to relatively small number of subjects). • No correlation between any effects (HS, SQ, SU) and duration of deafness of first and second deafened ear, average duration of deafness across ears, or these factors expressed as a fraction of age. 	<p>Bilateral CI users significantly benefit from head shadow, squelch, and summation effects, which are known effects for normal-hearing subjects.</p> <p>Bilateral CI reduces the performance gap between CI users and normal-hearing subjects for speech perception in noise.</p>

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<p>Schoen F, et al. Sound localization and sensitivity to interaural cues in bilateral users of the Med-El Combi 40/40+cochlear implant system. Otol Neurotol 2005;26:429-37. Cohort study</p>	<p>12 postlingually deafened adults bilaterally implanted with either the MED-EL CIS or CIS+. Adults</p>	<p>Assess sound localization and sensitivity to interaural cues.</p>	<p>Ability to identify which of 7 speakers sound was coming from, with and without unbalanced loudness of the two speech processors. Additional lateralization tests.</p>	<p>Bilateral CI users may:</p> <ul style="list-style-type: none"> • Regain ability to localize sound sources in the frontal horizontal plane. • Be able to translate interaural level differences into a lateral spatial shift. Rate of shift corresponds to that of normal hearing subjects. • Be sensitive to interaural time differences, with the time difference needed for complete lateralization potentially being similar to normal hearing subjects. 	<p>Bilateral CI can restore spatial hearing in CI users. Bilateral CI users potentially can localize sound sources and can show sensitivities to interaural level and time differences at rates corresponding to normal hearing subjects.</p>
<p>Schoen F, et al. Speech reception thresholds obtained in a symmetrical four-loudspeaker arrangement from bilateral users of MED-EL cochlear implants. Otol Neurotol 2002; 23:710-4. Cohort study</p>	<p>9 postlingually deafened adults with bilateral MED-EL CIs, implanted both sequentially (n=6) and simultaneously (n=3). Adults</p>	<p>Investigate speech reception in noise in subjects with bilateral multichannel CIs.</p>	<p>Prerecorded sentence tests in quiet and at various signal-to-noise ratios, performed in a symmetrical setup to eliminate head shadow effect. Subjects tested using both implants and the better implant only. From the results, the gain in SNRs at the speech reception threshold was determined.</p>	<ul style="list-style-type: none"> • All subjects showed substantial gain in SNRs (approximately 4 dB on average) that remained essentially stable for up to 4.4 years. • Subjects experienced a bilateral advantage shortly after implantation of the second CI and did not require a long period of learning, whether they had simultaneous or sequential procedures. • In this group, previous experience with a single CI neither favored nor impeded the reacquisition of binaural hearing. 	<p>Results showed a substantial and statistically significant bilateral benefit in this group. Bilateral CI users can process speech binaurally. Hypothesize that CI users benefit more from bilateral redundancy than individuals with normal hearing.</p>
<p>Seeber BU, et al. Localization ability with bimodal hearing aids and bilateral cochlear implants. J Acoust Soc Am 2004;116(3):1698-709. Case series</p>	<p>11 bimodal listeners (unilateral CI users with HA in other ear) and 4 bilateral MED-EL 40+ users.</p>	<p>Assess localization ability.</p>	<p>Ability to adjust spot of computer-controlled laser pointer to perceived direction of sound incidence in the frontal horizontal plane by rotating a trackball.</p>	<ul style="list-style-type: none"> • Bimodal group: 2 subjects w/ substantial residual hearing and 5 others w/ more pronounced hearing loss showed localization ability. 4 could already localize w/ single device. • Bilateral CI group: one subject showed near-normal localization accuracy and could also discriminate the side of sound origin using the first implanted device alone. The other 3 showed limited localization ability using both devices. One of these 3 demonstrated side-discrimination ability w/ 1st device only. 	<p>Successful restoration of localization ability in frontal horizontal plane is possible by means of bilateral CIs or, with sufficient residual hearing for one ear, with a CI/HA combination. Best performing subjects showed an accuracy near to normal-hearing subjects.</p>

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<p>Senn P, et al.</p> <p>Minimum audible angle, just noticeable interaural differences and speech intelligibility with bilateral cochlear implants using clinical speech processors. <i>Audiol Neurootol</i> 2005;10:342-52.</p> <p>Case-control study</p>	<p>5 postlingually deafened patients (2 female teens, 3 male adults) with bilateral CI systems (Medel C40+ or Medel C40) and 5 age-matched (± 2 years) normal-hearing persons.</p>	<p>Sound localization and speech intelligibility</p>	<p>Minimum audible angle (MAA) around the head in the horizontal plane.</p> <p>Speech intelligibility in noise and in quiet using standard test protocols</p>	<ul style="list-style-type: none"> • Speech intelligibility in noise: Percentage of correctly understood words was significantly higher using bilateral CI than only CI ipsilateral to noise source. Average increases of 33% (range 1–51%) on the left and 56% on the right, consistent with head shadow effect, were observed. • Localization: Best MAA values (3–8°) were only slightly higher than those of normal hearing controls. • Even after ≥ 1.5 years of bilateral CI use, later implanted ear does not perform as well as the first, but all subjects subjectively confirmed generally favorable test results using bilateral CI. All found substantial benefit from the first CI and only slightly less additional benefit from the second. 	<p>All patients benefited substantially from bilateral CI, which enables at least partial binaural hearing with near-normal interaural intensity discrimination and variable interaural time discrimination.</p> <p>When CI systems use the CIS speech coding strategy considered in this study, these abilities depend strongly on the type of acoustic stimulus.</p> <p>Ear canal or directional microphones or new coding strategies may increase bilateral CI benefit.</p>
<p>Summerfield AQ, et al.</p> <p>Self-reported benefits from bilateral cochlear implantation in post-lingually deafened adults: randomised controlled trial. <i>Int J Audiol</i> 2006; 45:1-9.</p> <p>Randomized clinical trial</p>	<p>24 post-lingually deafened adults with unilateral Nucleus CI24 (SPEAK) (previously implanted > 1 to 6 years; ages 29-82) randomized to immediate or delayed (12 month implantation of 2nd CI).</p>	<p>Test hypothesis that gain in health utility from 2nd implant is as small as estimated by hearing clinical informants (0.031 QALYs).</p>	<p>Condition-specific measures from SSQ questionnaire: Spatial hearing, Quality of Hearing, Hearing for Speech plus annoyance due to tinnitus; measured at 3 and 9 months.</p> <p>Generic QOL: Glasgow Health Status Inventory, HUI3, VAS overall QOL, EQ-5D.</p>	<ul style="list-style-type: none"> • Significantly better spatial hearing for bilateral, between groups ($p < 0.01$) and within groups ($p < 0.001$) at 3 and 6 mos. • Significantly better quality of hearing within group at 3 and 6 mos ($p < 0.001$); between groups at 9 mos only ($p < 0.01$) • Hearing for speech significantly better only within groups at 3 and 9 mos ($p < 0.05$) • Only significant QOL changes were improvement in GHSI at 9 mos and decrement in EQ-5D at 9 mos. Same measures showed significant improvement in unilateral; decrease attributed to worse tinnitus in 2 patients and mismatched electrode lengths in 1. 	<p>Significant increases in self-reported hearing did not translate into QOL improvement.</p> <p>Worse tinnitus with 2nd implant could have occurred by chance; need larger sample size to test.</p> <p>If overall change in tinnitus due to 2nd implant were 0, mean change in HUI3 at 9 mos would be 0.030, consistent with hypothesis.</p> <p>CUI would be €102,500/QALY.</p>

Study/Date/ Design	Participants	Objectives	Outcomes Measured	Results	Conclusions
<p>Tyler RS, et al. Three-month results with bilateral cochlear implants. <i>Ear Hear</i> 2002; 23(1 Suppl):80S-89S. Case series</p>	<p>9 postlingually deafened adults (ages 35 to 71, duration of deafness 1 mo-25 years) with bilateral Cochlear Corporation CI24M implants. Adults</p>	<p>Evaluate possible binaural listening advantages for speech recognition and localization after 3 months experience.</p>	<p>Sound localization and speech perception in quiet and noise. Words and sentences were presented with the signal always in the front and the noise from the front or either side.</p>	<ul style="list-style-type: none"> • Sentences/words: Statistically significant binaural advantages observed for both sentences and words for only 2 subjects. • Localization: Significant binaural advantage in 6 of 7 subjects tested. • Speech perception in noise: 4/9 had significant improvement w/ noise from the front, 1/9 w/ noise from the left, 3/9 w/ noise from the right. • All subjects showed a significant advantage of binaural versus monaural hearing for at least one of 4 speech perception measures. 	<p>Bilateral CIs can provide real advantages, esp. when utilizing the ear away from a noise source, thus taking advantage of head shadow effect.</p> <p>Localization ability was generally better with two implants than with one.</p> <p>Likely that fitting and signal processing will be important for achieving binaural advantages.</p> <p>All subjects preferred using both CIs. Results suggest that binaural benefits can be obtained with two different processors and even with an implant on one side and HA on the other.</p>
<p>Verschuur CA, et al. Auditory localization abilities in bilateral cochlear implant recipients. <i>Otol Neurotol</i>. 2005;26:965- 71. Cross-section from multi-center trial</p>	<p>20 of 29 bilaterally implanted subjects recruited from multicenter CI trial.</p>	<p>Quantify binaural advantage for auditory localization in the horizontal plane by bilateral CI recipients and determine whether use of dual microphones with one implant improves localization.</p>	<p>MAA. Each subject was tested with right implant alone, left implant alone, bilateral implant, and dual microphone.</p>	<ul style="list-style-type: none"> • Marked improvement in horizontal sound localization w/ bilateral compared to unilateral CI. • Small variation in bilateral performance; modest differences in localization performance for different stimuli. • Performance differences associated with level were relatively small and confined to unilateral conditions. • Bilateral benefit to localization was consistent for a range of stimuli with different temporal and spectral characteristics and for all subjects. 	<p>Magnitude of improvement in localization accuracy is worthwhile. Subjective reports from study participants supported the findings.</p> <p>Further work should investigate whether modifications in processing can improve benefit; relationship of performance and perceived benefit; whether localization benefits are generalizable across devices and for worse performers.</p>

Bilateral Cochlear Implantation Selected Bibliography

Study/Date/ Design	Participants	Objectives	Outcomes Measured	Results	Conclusions
<p>van Hoesel RJ, Tyler RS. Speech perception, localization, and lateralization with bilateral cochlear implants. J Acoust Soc Am 2003; 113:1617-30. Case series</p>	<p>5 bilateral CI users.</p>	<p>Assess localization abilities and speech understanding in noise, for both monaural and binaural listening conditions. Assess impact of variations in interaural time delays (ITDs) and interaural level differences (ILDs) on localization performance.</p>	<p>Localization and speech-in-noise with existing bilateral processors and new sound processing approach (SPEAR). Comparison of bilateral and unilateral performance.</p>	<ul style="list-style-type: none"> • Binaural localization abilities were clearly better than monaural using “better ear.” Binaural errors typically 3 times smaller than monaural. • For noise to either side, bilateral CIs showed substantial head-shadow benefit over unilateral CI use when noise was ipsilateral to the unilateral device (P < 0.001). • Lateralization studies showed consistently good sensitivity to ILDs; better than the smallest level adjustment available in the implants (0.17 dB) for some subjects. • Effects of interaural timing cues weaker than interaural level cues; ITD improvement dependent on low-rate information below a few hundred Hz. 	<p>Bilateral CI confers important benefits, both for localizing sounds in quiet and for listening in noise when signal and noise sources are spatially separated. Bilateral CIs can assist in everyday communication by improving ability to direct attention to appropriate location in noisy environments. Further work needed to determine whether timing related aspects can offer additional advantages over level-related benefits observed in this study.</p>
<p>NOTES: Excludes case reports with fewer than 3 subjects, abstracts of unpublished research, and technical papers without patient outcomes.</p>					