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THE CENTRAL AUDITORY SYSTEM AND COCHLEAR IMPLANTATION: USING OLFACTORY TESTING TO EVALUATE A POTENTIAL CENTRAL COMPONENT IN COCHLEAR IMPLANT PERFORMANCE

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Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Abstract

Background: Cochlear implantation is a highly successful intervention that, despite remarkable improvements in hardware and software, continues to show a high degree of variability in outcomes. Performance in adult patients can potentially be affected by the integrity of spiral ganglion neurons or by the performance of the central auditory system. Prolonged deafness and dementia are conditions that affect the central auditory system and can negatively impact cochlear implant outcomes. Central auditory test batteries can evaluate the central component of hearing in patients that have significant residual hearing, but cannot be effectively used in most cochlear implant patients. A wide variety of recent studies have shown that decline in olfaction predates and often predicts a variety of central nervous system degenerative disorders. We set out to evaluate if olfaction testing could predict hearing results after cochlear implantation.

Material and methods: Adult cochlear implant candidates were recruited and olfaction measured with the University of Pennsylvania smell identification test (UPSIT). Testing variables in the analysis include patient age, UPSIT score, AzBio +10 dB score at 6 months post activation, and change in AzBio +10 dB score from preoperative to post-activation testing times.

Results: Lower olfaction (UPSIT) scores correlated with poorer hearing outcomes (AzBio +10 dB) at 6 months post activation. Patients with lower UPSIT scores also showed less change in AzBio +10 dB scores over a 6-month period.

Conclusions: Olfactory testing may be useful in preoperative evaluation of cochlear implant patients. Identification of patients at risk for central auditory system dysfunction may be possible by evaluation of patients' olfactory function.

Key words: cochlear implant • central auditory processing • dementia • olfaction

LA VÍA AUDITIVA CENTRAL Y LA IMPLANTACIÓN COCLEAR: EL USO DEL TEST DE OLFATO EN LA EVALUACIÓN DEL COMPONENTE CENTRAL EN LA EFECTIVIDAD DEL IMPLANTE COCLEAR

Resumen

Introducción: La implantación coclear es un tratamiento altamente eficaz, sin embargo sigue proporcionando resultados muy desiguales a pesar de una mejora importante de los dispositivos y el software. Sobre la efectividad de un implante en pacientes adultos puede influir potencialmente la integridad de las neuronas del ganglio espiral de la cóclea, o bien el funcionamiento de la vía auditiva central. La sordera crónica o la demencia son condiciones que afectan el sistema nervioso central y que pueden comprometer los beneficios del implante coclear. Las baterías de los test de audición central permiten evaluar el componente central de la audición en pacientes que han preservado gran parte de los restos auditivos, sin embargo dichas herramientas no pueden utilizarse de manera eficaz en la mayoría de los pacientes con implante coclear. Muchos estudios recientes han demostrado que el empeoramiento del olfato está precedido, y a su vez muchas veces anuncia, múltiples enfermedades degenerativas del sistema nervioso central. El objetivo del presente trabajo es evaluar si los test de olfato pueden pronosticar resultados audiológicos tras la implantación coclear.

Material y métodos: Al test de olfato UPSIT (ing. *University of Pennsylvania Smell Identification Test*) se sometieron candidatos adultos para la implantación coclear. Se analizaron las variables tales como: la edad del paciente, los resultados del test UPSIT, el resultado del test AzBio +10dB 6 meses tras la activación del implante, así como el cambio entre resultados obtenidos por AzBio +10dB antes de la implantación y una vez activado el implante.

Resultados: Una menor sensibilidad del olfato (según UPSIT) correspondía con peores resultados audiológicos (según AzBio +10 dB) 6 meses tras la activación del implante. En pacientes que obtuvieron peores resultados del test UPSIT se observó una menor variabilidad de los resultados AzBio +10dB en el periodo de 6 meses.

Conclusiones: Los test de olfato pueden resultar útiles en la evaluación de pacientes antes de la implantación coclear. La evaluación del funcionamiento del olfato puede permitir la identificación de pacientes que corren el riesgo de padecer una disfunción en la vía auditiva central.

Palabras clave: implante coclear • procesamiento auditivo central • demencia • olfato

ЦЕНТРАЛЬНЫЙ СЛУХОВОЙ ПУТЬ И КОХЛЕАРНАЯ ИМПЛАНТАЦИЯ: ИСПОЛЬЗОВАНИЕ ИССЛЕДОВАНИЯ ОБОНЯНИЯ ДЛЯ ОЦЕНКИ ПРЕДУСМАТРИВАЕМОГО ЦЕНТРАЛЬНОГО КОМПОНЕНТА В ЭФФЕКТИВНОСТИ КОХЛЕАРНОГО ИМПЛАНТАТА

Изложение

Введение: Кохлеарная имплантация – это необыкновенно эффективная процедура, однако до сих пор она приносит очень дифференцированные результаты, несмотря на значительное усовершенствование оборудования и программного обеспечения. На эффективность имплантата у взрослых пациентов потенциально может влиять интегральность нейронов спирального ганглия улитки или же функционирование центрального слухового пути. Длительная глухота или деменция – это состояния, воздействующие на центральную нервную систему, которые могут оказывать отрицательное влияние на преимущества использования кохлеарного имплантата. При использовании батареи центральных тестов можно оценить центральный компонент слуха пациентов, которые в значительной степени сохранили остатки слуха, однако данные инструменты не получится использовать эффективным образом у большей части пациентов с кохлеарным имплантатом. Большое количество исследований последних лет показало, что ухудшению обоняния предшествует и одновременно его часто предвещает большое количество дегенеративных болезней центральной нервной системы. Целью настоящей работы является оценка, могут ли исследования обоняния прогнозировать аудиологические результаты после кохлеарной имплантации.

Материал и методы: Для исследования обоняния с помощью идентификационного теста UPSIT (англ. *University of Pennsylvania Smell Identification Test*) были выбраны взрослые кандидаты на установку кохлеарного имплантата. Были проанализированы такие переменные, как возраст пациента, результат теста UPSIT, результат исследования батареей AzBio +10дБ через 6 месяцев после активации имплантата и изменение результатов, полученных в AzBio +10дБ, перед имплантацией и после активации имплантата.

Результаты: Более слабое обоняние (по UPSIT) кореллировало с более низкими аудиологическими результатами (по AzBio +10 дБ) через 6 месяцев после активации имплантата. У пациентов, которые получили более низкие результаты в тесте UPSIT, наблюдалась меньшая изменчивость результатов AzBio +10 дБ в течение 6 месяцев.

Выводы: Исследования обоняния могут быть полезны при оценке пациентов перед кохлеарной имплантацией. Оценка функционирования обоняния пациентов может сделать возможной идентификацию тех пациентов, у которых существует опасность дисфункции центрального слухового пути.

Ключевые слова: кохлеарный имплантат • центральный слуховой анализатор • деменция • обоняние

OŚRODKOWA DROGA SŁUCHOWA A IMPLANTACJA ŚLIMAKOWA: WYKORZYSTANIE BADANIA WĘCHU DO OCENY PRZEWIDYWANEJ KOMPONENTY CENTRALNEJ W EFEKTYWNOŚCI IMPLANTU ŚLIMAKOWEGO

Streszczenie

Wprowadzenie: Implantacja ślimakowa to zabieg niezwykle skuteczny, jednak nadal przynoszący wysoce zróżnicowane rezultaty, mimo znaczącego udoskonalania sprzętu i oprogramowania. Na efektywność implantu u dorosłych pacjentów potencjalnie wpływać może integralność neuronów zwoju spiralnego ślimaka lub też funkcjonowanie ośrodkowej drogi słuchowej. Przedłużająca się głuchota lub demencja to stany oddziałujące na ośrodkowy układ nerwowy, które mogą wpływać negatywnie na korzyści z implantu ślimakowego. Przy użyciu baterii testów centralnych można ocenić centralną komponentę słyszenia pacjentów, którzy w znacznym stopniu zachowali resztki słuchowe, jednak narzędzi tych nie można wykorzystać w sposób efektywny u większości pacjentów z implantem ślimakowym. Wiele ostatnich badań wykazało, iż pogorszenie węchu poprzedza, a zarazem często zapowiada wiele chorób degeneracyjnych ośrodkowego układu nerwowego. Celem niniejszej pracy jest ocenienie, czy badania węchu mogą prognozować wyniki audiologiczne po implantacji ślimakowej.

Materiał i metody: Do badania węchu testem UPSIT (ang. *University of Pennsylvania Smell Identification Test*) włączono dorosłych kandydatów do implantu ślimakowego. Przeanalizowano zmienne takie jak: wiek pacjenta, wynik testu UPSIT, wynik badania baterią AzBio +10dB na 6 miesięcy po aktywacji implantu oraz zmianę wyników uzyskanych w AzBio +10dB przed implantacją i po aktywacji implantu.

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Wyniki: Słabsze powonienie (wg UPSIT) korelowało z niższymi wynikami audiologicznymi (wg AzBio +10 dB) na 6 miesięcy po aktywacji implantu. U pacjentów, którzy uzyskali słabsze wyniki w teście UPSIT zaobserwowano mniejszą zmienność wyników AzBio +10dB w okresie 6 miesięcy.

Wnioski: Badania węchu mogą być użyteczne w ocenie pacjentów przed implantacją ślimakową. Ocena funkcjonowania węchu pacjentów może umożliwić identyfikację tych pacjentów, u których istnieje ryzyko dysfunkcji ośrodkowej drogi słuchowej.

Słowa kluczowe: implant ślimakowy • centralne przetwarzanie słuchowe • demencja • węch

Background

Cochlear implantation has been shown to successfully rehabilitate hearing in a variety of patient populations. Despite this broad utility, there continues to be significant variability in patient outcomes. A number of different factors have been defined that can affect device outcomes, including the integrity of the peripheral auditory system, device related issues including processing strategy and number of active channels [1–4], duration of profound deafness [5], the central auditory system's ability to process degraded speech [6], and, in pre-lingually deafened patients, the time at implantation [7–10]. Additional factors include the degree of residual hearing present at time of implantation [11]. Recent cochlear implant research has focused on implantation in the elderly [12–14]. Most studies demonstrate that cochlear implantation in the elderly is an effective intervention that restores the individual's ability to communicate and may help maintain independence. Several studies have shown that on average elderly patients have slightly lower speech scores than younger patients [15,16]. Identifying potential causes of differences between more and less functional populations of cochlear implant patients could lead to improved treatment and rehabilitation strategies. Recent studies have identified electrophysiologic tests that can identify peripheral factors that affect cochlear implant outcomes [17]. Cognitive factors have also been hypothesized to affect cochlear implant outcomes, especially when analyzing degraded speech [18]. Emerging evidence suggests that central or "top down" processes play a significant role in speech understanding [19].

The American Speech-Language-Hearing Association defines "central auditory processing" as a term that refers to the efficiency and effectiveness by which the central nervous system utilizes the auditory signals it receives. Examples of central auditory processing include sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of hearing, and auditory performance in competing acoustic signals. A central auditory processing disorder refers to poor performance in one of the abilities listed above [20]. In a similar progression to the research regarding olfaction in neurodegenerative diseases, central auditory dysfunction was shown to be associated with Alzheimer's disease [21–23], then to be a precursor to Alzheimer's dementia [24]. Research has been performed on the neuropathologic changes of the aging central auditory system [25–27], but not to the extent that it has been directed to changes in the olfactory tract that occur in the setting of neurodegenerative diseases.

Given that poor performance on olfactory tests is predictive of development of a variety of central nervous system degenerative processes that are also associated with central auditory dysfunction, we hypothesize that patients with olfactory dysfunction are more likely to have worse hearing outcomes after cochlear implantation.

Material and Methods

Subjects and hearing testing

Protocols and data collection were reviewed and approved by the institutional review board. We collected data on 24 patients with unilateral implants and 5 patients with bilateral implants for a total of 34 ears analyzed. Adult (>18 years) patients with a history of progressive hearing loss that met FDA criteria for cochlear implantation were enrolled. Ages ranged from 45 to 82 with a mean of 69. To limit variability in data, patients with greater than 10 years of profound hearing loss and patients with congenital deafness were excluded from analysis. Additionally we only analyzed patients with one type of cochlear implant to limit device-related factors. All patients underwent preoperative and postoperative evaluation using the testing recommendations outline in the Minimum Speech Test Battery for Adult Cochlear Implant Users 2011 (*http://www.auditorypotential.com/MSTBfiles/MSTBManual2011-06-20%20.pdf*). The AzBio test at +10 dB SNR was administered preoperatively and at 6 months after implantation. Preoperatively, testing was done in the best-aided condition binaurally, and postoperatively, with a cochlear implant, only for each ear [28].

Olfaction testing

Olfaction testing was carried out using a commercially available version of the University of Pennsylvania Smell Identification Test (UPSIT) (Sensonics Inc., Haddon Heights, NJ). This suprathreshold test is a self-administered test consisting of 40 items and the score out of 40 possible points was recorded.

Statistical methods

Testing variables in the analysis include patient age, UPSIT score, AzBio +10 dB score at 6 months post activation, and change in AzBio +10 dB score from preoperative to post activation testing times. Normality of data was calculated using the D'Agostino-Pearson omnibus normality test. Subsequently Pearson correlation coefficients and a two-tailed *t*-test ($p<0.05$ significance) were calculated using Prism v 7.0a.

Results

There was no correlation between patient age and their AzBio +10 dB score 6 months post implantation (Pearson $r=0.18$, $p=0.3385$) or with the total UPSIT score (Pearson $r=-0.19$, $p=0.3315$).

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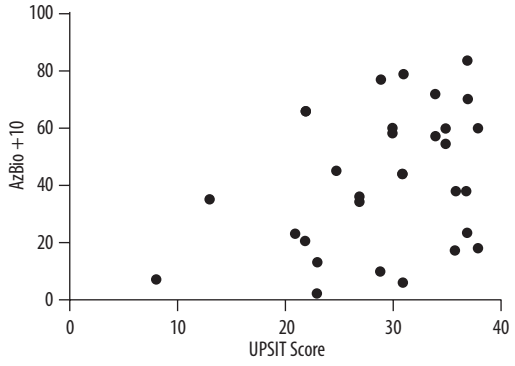

Figure 1. Scatter plot shows a significant correlation between UPSIT score and the AzBio +10 dB post-activation hearing score

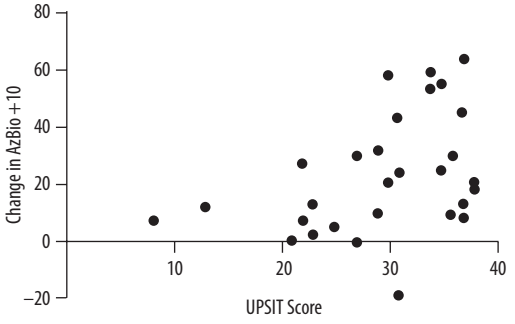

Figure 2. Scatter plot with a significant correlation between UPSIT score and the change in AzBio +10 dB score between preoperative and post-activation testing

There was a significant correlation between the UPSIT score and the AzBio +10 dB post activation (Pearson r=0.38, p=0.04). There was also a positive correlation between the UPSIT score and the change in AzBio +10 dB score from preoperative to post activation testing times (Pearson r=0.43, p=0.03) (Figures 1, 2).

Discussion

Many different factors affect implant performance in adult patients, including duration of deafness, integrity of the peripheral auditory system, and central auditory function. Dementia has been speculated to have a negative impact on cochlear implant outcomes, but no large studies have examined this in detail. Currently, studies are underway examining the impact of changes in a variety of cognitive tests on cochlear implant outcomes. Several studies have shown that alteration of olfaction may predate cognitive decline, suggesting that olfaction testing may allow earlier detection of central nervous system degeneration than does cognitive testing.

The UPSIT test was developed in the early 1980s and has been shown to be reliable, to correlate significantly with traditional odor-detection thresholds, to provide means for detecting malingering, and to clearly differentiate between patients with normal olfactory ability and those with olfactory dysfunction [29].

Patients with Alzheimer's dementia [30,31] and other neurodegenerative diseases (including Parkinson's [31], Huntington's [32], Korsakoff [33], and ALS [34]) have been shown to perform poorly on smell tests. Poor performance on smell tests has also been shown to be predictive of cognitive decline and development of Alzheimer's dementia [35–37]. Hyposmia has also been shown to be predictive of development of dementia in Parkinson's disease [38]. Pathological changes have been shown to occur throughout the length of the olfactory tract in neurodegenerative diseases, from the olfactory epithelium to the primary olfactory cortex and its secondary targets. These changes occur secondary to deposition of pathologic proteins and neurofibrillary tangles; Attems and colleagues provide a thorough review of the neuropathological and pathophysiological changes of the olfactory system in these diseases [39].

In the current study a moderate correlation between the UPSIT score and cochlear implant outcomes was found. Analysis of phoneme-based word tests such as the CNC (consonant-vowel nucleus-consonant) is thought to weight the function of the peripheral auditory system [40]. We therefore selected the AzBio score in background noise as an outcomes measure, avoiding ceiling effects with easier tests and providing patients with a degraded auditory signal that would require maximum central auditory effort to achieve speech understanding. Both the post-op AzBio +10 dB score and the improvement in this score from preoperative to post-activation testing times correlated to UPSIT scores, with lower olfaction correlating with poorer outcomes. Interestingly, there was no correlation between hearing outcomes and age or olfaction and age in this cohort. Based on R^2, approximately 16% of the outcomes effect can be attributed to this correlation. Looking at overall outcomes, it is clear that some of the patients with excellent UPSIT scores had poor performance. Other forms of analysis may identity the underlying cause of poor implant performance in patients in this population.

There are multiple confounding factors that need to be considered. This study did not consider peripheral auditory system integrity and the sample size was small. Future studies will combine preoperative measures of peripheral auditory system function with olfactory testing to attempt to identify patients at risk of poor performance.

Conclusions

Olfactory testing may be useful in preoperative evaluation of cochlear implant patients. Identification of patients at risk for poor hearing outcomes may be possible by evaluation of patients' olfactory function. The results of this pilot study may stimulate future studies into how cognitive function may affect the ability to integrate a cochlear implant into hearing function.

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