McMaster University | Health Forum

Rapid Evidence Profile

Diagnosing central auditory processing disorder

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Context

- Military service members and Veterans face a higher risk of auditory processing disorders due to their exposure to blast injuries, hazardous noise levels, and neurotrauma.
- Central auditory processing disorder is a constellation of functional hearing deficits that may develop in adults with otherwise normal audiometric thresholds and can disrupt their ability to understand speech and localize sound.
- Diagnosing and treating central auditory processing disorder is challenging, particularly because it often occurs alongside other neurological and psychological conditions.
- This rapid evidence profile summarizes recent research on central auditory processing disorder, focusing on diagnostic methods and its relationship with traumatic brain injury.
- While this profile provides insights from existing evidence, it should not be used in place of systematic reviews or meta-analyses when developing clinical guidelines or practice recommendations.

Box 1: Evidence and other types of information

+ Global evidence drawn upon

Evidence syntheses selected based on relevance, quality, and recency of search

+ Forms of domestic evidence used (🍁 = Canadian)

Data analytics | Evaluation | Guidelines

*** Additional notable features**

Prepared in the equivalent of three business days using an 'all hands-on deck' approach

Questions

1) What is the diagnostic standard in the medical literature for central auditory processing disorder?
2) Is central auditory processing disorder a stand-alone diagnosis separate and distinct from sensorineural hearing loss?
3) Is there a causative relationship between the onset of central auditory processing disorder and traumatic brain injury?

High-level summary of key findings

- We identified 24 evidence documents, of which we determined 17 to be highly relevant to one or more of the three questions focused on for this rapid evidence profile.
- These highly relevant evidence documents include three evidence syntheses, four guidance documents, and 10 single studies.
- For question one, we identified four guidance documents (one from Canada, one from New Zealand, and two from the U.S.), which showed agreement on a definition of central auditory processing disorder as well as on the role of audiologists in providing a diagnosis of the condition.

- The four guidelines also point to the need to undertake screening for the condition as well as a battery of behavioural tests for auditory processing, but they note there is currently no standardized approach to determine which tests should be included.
- Current diagnostic criteria from all four guidelines require that performance deficits are noted in one or both ears of at least two standard deviations below the mean on two or more tests in the testing battery for auditory processing, or if the result of one test falls at least three standard deviations below the mean.
- We did not identify any evidence documents relevant to question two.
- For question three, while many included evidence documents note a significant association between traumatic brain injury and auditory processing challenges, this was not consistent across all included documents.
- Further, a lack of baseline testing, heterogeneity in the diagnosis of traumatic brain injury, and uncertainty of the effects of comorbid conditions limited conclusions on causality.
- Additional research should focus on establishing a gold standard for testing for central auditory processing disorder, and gaining increased clarity on the similarities and differences in auditory processing for traumatic brain injuries acquired from blast exposure compared to those acquired from more conventional causes.

Box 2: Approach and supporting materials

At the beginning of each rapid evidence profile and throughout its development, we engage a subject matter expert, who helps us to scope the question and ensures relevant context is taken into account in the summary of the evidence.

We identified evidence addressing the question by searching ACCESSSS, PubMed, Scopus, Guidelines International Network, and Veterans Affairs and Department of Defence Clinical Practice Guidelines. All searches were conducted on 23 October 2024. The search strategies used are included in Appendix 1. In contrast to synthesis methods that provide an in-depth understanding of the evidence, this profile focuses on providing an overview and key insights from relevant documents.

We searched for full evidence syntheses (or synthesis-derived products such as overviews of evidence syntheses) and protocols for evidence syntheses.

We appraised the methodological quality of evidence syntheses that were deemed to be highly relevant using the first version of the AMSTAR tool. AMSTAR rates overall quality on a scale of 0 to 11, where 11/11 represents a review of the highest quality, medium-quality evidence syntheses are those with scores between four and seven, and low-quality evidence syntheses are those with scores less than four. The AMSTAR tool was developed to assess reviews focused on clinical interventions, so not all criteria apply to evidence syntheses pertaining to delivery, financial, or governance arrangements within health systems or implementation strategies.

A separate appendix document includes:

- methodological details (Appendix 1)
- details about each identified guidance document (Appendix 2)
- details about each identified evidence synthesis (Appendix 3)
- details about each identified single study (Appendix 4)
- documents that were excluded in the final stages of review (Appendix 5).

This rapid evidence profile was prepared in the equivalent of three days of a 'full court press' by all involved staff.

Framework to organize what we looked for

- Diagnosis of central auditory processing disorder
  - Criteria for diagnostic testing
    - Recent experience of symptoms of central auditory processing disorder
      - Difficulty localizing sound

        - Difficulty understanding spoken language in loud/reverberant environments
        - Frequent requests for repetitions
        - Difficulty following auditory directions
        - Difficulty paying attention
      - Family history of hearing loss
      - Presence of occupational exposures (such as those that may occur during special operations)
        - Blast exposure
        - Exposure to pressurized environments
        - Jet fuel and solvents exposure
        - Noise exposure that exceeds normal levels
          - Firearms and heavy weapons
          - Jets and aircrafts
          - Other machinery
  - Health professionals responsible or involved in making a diagnosis of central auditory processing disorder
    - Audiologists
    - Neurologists
    - Speech-language pathologists
    - Psychologists
  - Requirements of health professionals responsible or involved in making a diagnosis
  - Methods for diagnosis of central auditory processing disorder
    - Behavioural/psychophysical measures
      - Binaural interaction (including dichotic listening tests)
      - Monaural low-redundancy speech tests
      - Temporal processing
      - Auditory discrimination
    - Electrophysiological tests
      - Auditory brain stem response
      - Long-latency auditory-evoked potentials
  - Presence of comorbidities
    - ADHD
    - Anxiety disorder
    - Clinical depression
    - Traumatic brain injury
    - Post-traumatic stress disorder
- Causality criteria for establishing association between traumatic brain injury and central auditory processing disorder
  - Temporal relationship (e.g., exposure must precede the occurrence of the outcome)
  - Strength of association (e.g., association should be statistically significant to demonstrate that it was not simply a chance occurrence)
  - Dose-response relationship (e.g., evidence that increasing exposure increases the risk of the outcome)
  - Consistency of evidence (e.g., similar or the same results generated by studies using different methods in different settings)
  - Specificity (e.g., the exposure is the only cause of the outcome that can be shown)
  - Biological plausibility and coherence (e.g., the association between the exposure and outcome should be plausible and consistent with current knowledge)

What we found

We identified 24 evidence documents, of which we determined 17 to be highly relevant, including:

- three evidence syntheses
- four guidance documents
- 10 single studies.

Coverage by and gaps in existing evidence syntheses and domestic evidence

Though the identified evidence largely covers the domains of the organizing framework included above, we identified gaps in the literature that led to challenges answering the questions posed for this rapid evidence profile.

In general, there is a lack of high-quality synthesized evidence related to acquired central auditory processing disorder, such as the type that would be found among military service members and Veterans. The evidence syntheses that were identified focused predominantly on the validity and reliability of behavioural tests for identifying auditory processing deficits, or on the treatment and management of auditory processing deficits (a topic that was out of scope for this rapid evidence profile). While we did identify four clinical practice guidelines related to question one, three of these are over 10 years old and do not include references to military or Veteran populations specifically. In addition, we did not identify any evidence documents related to question two.

For question three, two limitations in the identified evidence are worth noting. The first is the tendency of the literature to focus on the relationship between blast exposure and auditory processing deficits without a diagnosis of traumatic brain injury. The literature noted that this is done to avoid the challenges that are present in diagnosing traumatic brain injury, particularly mild traumatic brain injury in military and Veteran populations. These studies are included in the appendix but have been coded as being of medium and low relevance. The second is the lack of agreed-upon standards for the testing and diagnosis of central auditory processing disorder. Much of the identified evidence examines the relationship between traumatic brain injuries and auditory processing challenges without a determination of whether these deficits are sufficient to meet a clinical diagnosis. The identified evidence does not make definitive statements about the causal relationship between these two conditions.

Key findings from included evidence documents

Question 1: What is the diagnostic standard in the medical literature for central auditory processing disorder?

We identified four guidance documents, two recent high-quality evidence syntheses, and three single studies related to this question. The three guidance documents include practice guidelines from the Canadian Interorganizational Steering Group for Speech-Language Pathology and Audiology (CISG), the American Speech-Language-Hearing Association (ASHA), the American Academy of Audiology (AAA), and the New Zealand Audiological Society (NZAS).(1-4)

While our search also identified guidelines from the British Society of Audiology and the German Society for Phoniatrics and Pediatric Audiology, both were specific to developmental auditory processing disorder rather than secondary or acquired auditory processing disorder. We did not identify any guidance specifically related to active military members or Veterans. We summarize the key findings from these guidance documents and from related evidence syntheses and single studies, and additional details are provided in Appendix 2, 3, and 4.

<u>Definition of central auditory processing disorders</u>

The AAA and ASHA use a common definition of central auditory processing disorder that is consistent with the definition in the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10 CM). The term central

auditory processing disorder is used to refer to deficits in the neural processing of auditory information in the central auditory nervous system demonstrated by poor performance in one or more of the following skills:

- sound localization and lateralization
- auditory discrimination
- auditory pattern recognition
- temporal aspects of audition
- auditory performance in competing acoustic signals
- auditory performance with degraded acoustic signals.(3; 4)

Though the CISG and NZAS use broadly similar definitions, they add additional context that includes both challenges with auditory processing capacity, defined as executive tasks in standardized environments, and challenges with auditory processing performance, defined as executing tasks in the everyday environment.(1; 2) These guidelines also note different types of auditory processing disorder and define acquired auditory processing disorder (such as the type that some active service members and Veterans would experience) as "cases that are associated with a known event that could plausibly explain the auditory processing disorder."(1; 2)

None of the included evidence syntheses or single studies explicitly examine different definitions or their components for central auditory processing disorder (or auditory processing disorder).

Role and responsibility of healthcare providers in relation to diagnosis

Only the four guidelines explicitly note the roles of different professionals in diagnosing central auditory processing disorder. All four guidelines agree that an audiologist should provide diagnosis, but the audiologist may benefit from sharing the results of assessments or undertaking other complementary assessments with a multidisciplinary team that may include a speech-language pathologist, psychologist, and physician.(1-4)

All four of the guidelines note that audiologists responsible for diagnosing central auditory process disorder should have an up-to-date clinical knowledge base that is inclusive of auditory processing disorder, and they should be trained in the administration and interpretation of screening, behavioural, and electrophysiological tests.(1-4) The Canadian guidelines also note that diagnosing professionals should be expected to have up-to-date knowledge of community resources available to help the client following the diagnosis.(1)

Screening and testing battery for diagnosis

The guidelines note that there is no universally accepted method for screening adults with acquired central auditory processing disorder. However, there is consensus from the four guidelines that screening should include a detailed case history, self-assessment tools, or behavioural checklists and tests for peripheral hearing loss.

Concerning self-assessment tools and behavioural checklists, the guidance document from New Zealand recommends the use of the Speech, Spatial and Qualities of Hearing Scale or Hearing Handicap Inventory for Adults.(2) However, one recent medium-quality evidence synthesis identified the Amsterdam Inventory for Auditory Disability and Handicap, Speech, Spatial and Qualities of Hearing Scale and the Hyperacusis Questionnaire as being helpful for accurately separating adults with auditory processing disorders from those without, as well as for identifying those with more significant deficits in auditory processing as compared to those with other clinical diagnoses.(5)

With respect to tests for peripheral hearing loss, the following tests are recommended in the CISG, NZAS, and AAA guidelines:

- pure-tone audiometry
- immittance battery
- speech/word recognition

- otoacoustic emissions
- speech in noise test.(1-3)

There is currently no agreed upon standard for the battery of tests that should be run to diagnose central auditory processing disorder. Each of the guidelines include lists of appropriate behavioural and at times electrophysiological tests for the diagnosis of central auditory processing disorder, which have been extracted as part of Appendix 2. However, more relevant to highlight are principles from the ASHA guidelines that may influence a professional's decision about the composition of a test battery. These include the need to:

- centre the process around the complaints and relevant information available rather than using a specific test-driven approach
- include measures that are sensitive to the integrity of the central auditory nervous system
- examine different central processes, tasks, and the integrity of multiple regions of the central auditory nervous system
- consider age and developmental status
- include both verbal and non-verbal stimuli in the testing battery
- monitor attention, motivation, and energy levels throughout the testing process.(4)

In addition, guidelines note the need to balance the use of multiple tests to reduce diagnostic error with the potential for false positives and increased costs. The AAA guideline advises diagnosing professionals to select the minimum number of tests necessary to provide the best overall sensitivity and specificity.(3)

In addition to findings from the four guidelines, one recent high-quality evidence synthesis and three recent single studies include findings related to the accuracy of tests for diagnosing central auditory processing disorder. One recent high-quality evidence synthesis found the use of Duration Pattern Tests, Frequency Pattern Tests, and Gaps in Noise Tests as all being reliable tests for the diagnosis of central auditory processing disorder in adults.(6) One recent study found that behavioural tests for binaural interaction (including dichotic listening tests) and temporal processing effectively detected differences in functional hearing and communication deficits among active service members with blast exposure compared to a control group with no blast exposure.(7) A second recent single study found the use of extended high-frequency audiometry and temporal processing tests accurately detected 'hidden hearing loss' among police officers in India.(8) Finally, a third recent single study reported that electrophysiological tests for P2 and P3 latency measures may be effective in validating subjective auditory processing difficulties among blast-exposed Veterans.(9)

<u>Criteria for diagnosis</u>

Current diagnostic criteria from all four guidelines require that performance deficits are noted in one or both ears of at least two standard deviations below the mean on two or more tests in the testing battery for auditory processing. In addition, the CISG, NZAS, and ASHA note that a diagnosis may be made based on poor performance on only one test, if the results fall at least three standard deviations below the mean or the finding is accompanied by significant functional difficulty in auditory behaviours that rely on the process being assessed.(1-4)

Question 2: Is central auditory processing disorder a stand-alone diagnosis separate and distinct from sensorineural hearing loss?

We did not identify any evidence syntheses, single studies, or clinical practice guidelines that directly addressed this question. However, each of the four clinical practice guidelines speak to a diagnosis of central auditory processing disorder (or auditory processing disorder) and do not mention any additional diagnosis of sensorineural hearing loss.

Question 3: Is there a causative relationship between the onset of central auditory processing disorder and traumatic brain injury?

We included one evidence synthesis and seven single studies that addressed question three. While there does seem to be some consistency in findings that many individuals experiencing traumatic brain injury also experience challenges with auditory processing, we were unable to determine whether or not there is a causal relationship. This is largely due to three limitations in the identified evidence:

- no baseline testing of auditory processing prior to exposures
- a lack of consistent diagnoses of traumatic brain injuries (particularly mild traumatic brain injuries)
- known limitations in the diagnosis of central auditory processing disorder (as outlined in the section above).

A summary of the identified evidence organized by each of the criteria for establishing causality is provided below.

With respect to a temporal relationship, though self-reported measures and a detailed case history are used in all studies to establish temporality, none of the included evidence syntheses or single studies had a baseline assessment of auditory processing prior to a diagnosis of traumatic brain injury.

For strength of association, one evidence synthesis and seven single studies reported on the association between traumatic brain injury (including mild traumatic brain injury) and auditory processing challenges.(10-17) Though many of the included evidence documents (one evidence synthesis and four single studies) found a significant positive correlation between traumatic brain injuries and one or more auditory processing challenges, some studies had mixed findings.(10-17) In particular, three studies report that they did not identify a significant association. The first single study comparing auditory processing among blast-exposed Veterans (about half of whom had a diagnosis of mTBI) against that of a control group of non-blast-exposed Veterans found that an mTBI diagnosis is not strongly correlated with the number of abnormal test performances.(15) Similarly, the second recent single study also found traumatic brain injury is not strongly associated with self-reported auditory processing challenges, but post-traumatic stress disorder was strongly associated with self-reported auditory processing challenges.(16) The third single study compared the auditory brainstem response of individuals with non-blast related mild traumatic brain injuries to a control group and identified no significant differences for either electrophysiological tests using click or speech stimuli.(14) All three studies note that these findings may, at least in part, be due to heterogeneity in the diagnosis of mild traumatic brain injuries.

Only one single study directly examined the dose-response relationship. The recent single study compared measures of auditory event-related potentials in individuals with no history of blast exposure, those with a history of single blast-related mild traumatic brain injuries, and those with multiple blast-related mild traumatic brain injuries (three or more). Individuals with a previous blast-related mild traumatic brain injury diagnosis were found to have reduced attention and ability to prioritize important sounds (auditory event-related potential metrics for N100 and N200) as compared to a control group.(13) Those with a history of repetitive blast-related mild traumatic brain injuries were reported to have lower pre-attentional filtering of sensory information (auditory event-related potential metrics for P50) compared to those with a non-repetitive history or with no history of mild traumatic brain injury.(13)

With respect to the consistency of evidence, a positive association was generally reported between traumatic brain injury and measures of auditory processing deficits, except for the previously three noted single studies. This evidence was generated within one evidence synthesis and single studies that use a range of different methods, including cohort studies, cross-sectional studies, and case-control studies.(10-17) However, the majority of the evidence documents focus on traumatic brain injuries diagnosed following exposure to one (or multiple) explosions. Moreover, only two single studies examined auditory processing disfunction in individuals with non-blast related traumatic brain injuries, which found conflicting results despite using the same cohort of individuals, possibly indicating that auditory processing challenges are not universal with all mild traumatic brain injuries but rather among a subset of those affected.(14; 17)

Though many of the included evidence documents report adjusting for particular characteristics of included participants, such as the number of traumatic brain injuries, length of time since traumatic brain injury, and conducting multiple types of behavioural and electrophysiological tests, the specificity of the association remains unclear given the noted

heterogeneity in the diagnosis of traumatic brain injuries and uncertainty of the effects of other comorbidities including post-traumatic stress disorder and depression.

Apart from discussing the general biology of traumatic brain injury and its possible effects on auditory processing, findings from the included evidence documents do not specifically address the biological plausibility of the association.

Next steps based on the identified evidence

As the evidence on this topic is still evolving, there are many next steps to fill essential gaps in knowledge to guide clinical practice, which include:

- establishing a gold standard for a testing battery for central auditory processing disorder
- greater understanding between the similarities and differences in auditory processing from traumatic brain injuries acquired from blast exposure compared to those acquired from conventional causes (e.g., sports, motor vehicle accidents)
- cohort studies that establish a baseline for auditory processing and support an improved understanding of temporality in examining the association between traumatic brain injuries and auditory processing
- additional research efforts that clarify the role of post-traumatic stress disorder, depression, and aging on auditory processing.

References

1. Canadian Interorganizational Steering Group for Speech-Language Pathology and Audiology. Canadian guidelines on auditory processing disorder in children and adults: Assessment and intervention. Ottawa: CISG; 2012.
2. Keith W, Purdy S, Baily M, Kay F. New Zealand guidelines on auditory processing disorder. Auckland: New Zealand Audiological Society; 2019.
3. Musiek F, Baran J, Bellis T, et al. Diagnosis, treatment and management of children and adults with central auditory processing disorder. Reston, VA: American Academy of Audiology; 2010.
4. American Speech-Language-Hearing Association. Central auditory processing disorder [Practice portal]. Rockville, MD: ASHA; n.d. https://www.asha.org/practice-portal/clinical-topics/central-auditory-processing-disorder/#collapse_5 (last visited 7 March 2025).
5. Samara M, Thai-Van H, Ptok M, et al. A systematic review and metanalysis of questionnaires used for auditory processing screening and evaluation. *Frontiers in Neurology* 2023; 14: 1243170.
6. Chowsilpa S, Bamiou DE, Koohi N. Effectiveness of the auditory temporal ordering and resolution tests to detect central auditory processing disorder in adults with evidence of brain pathology: A systematic review and meta-analysis. *Frontiers in Neurology* 2021; 12: 656117.
7. Grant KW, Phatak SA, Myers JR, Jenkins KA, Kubli LR, Brungart DS. Functional hearing difficulties in blast-exposed service members with normal to near-normal hearing thresholds. *Ear and Hearing* 2024; 45(1): 130-141.
8. Dhrruvakumar S, Shambhu T, Konadath S. Assessment of hidden hearing loss in individuals exposed to occupational noise using cochlear, neural, temporal functions and quality of life measures. *Indian Journal of Otolaryngology Head and Neck Surgery* 2022; 74(Suppl 1): 524-531.
9. Papesh MA, Stefl AA, Gallun FJ, Billings CJ. Effects of signal type and noise background on auditory evoked potential N1, P2, and P3 measurements in blast-exposed Veterans. *Early Hearing* 2021; 42(1): 106-121.
10. Vanbilsen N, Kotz SA, Rosso M, Leman M, Triccas LT, Feys P, Moumdjian L. Auditory attention measured by EEG in neurological populations: Systematic review of literature and meta-analysis. *Science Reports* 2023;13(1): 21064.
11. Koebli JR, Balasubramanian V, Zipp GP. An exploration of higher-level language comprehension deficits and factors influencing them following blast TBI in US veterans. *Brain Injury* 2020; 34(5): 630-641.
12. Papesh MA, Koerner T. Clinical gaps-in-noise measures in blast-exposed Veterans: Associations with electrophysiological and behavioral responses. *Seminars in Hearing* 2024; 45(1): 83-100.
13. Manning Franke L, Perera RA, Aygemang AA, et al. Auditory evoked brain potentials as markers of chronic effects of mild traumatic brain injury in mid-life. *Clinical Neurophysiology* 2021; 132(12): 2979-2988.
14. Vander Werff KR, Rieger B. Brainstem evoked potential indices of subcortical auditory processing after mild traumatic brain injury. *Ear and Hearing* 2017; 38(4): e200-e214.
15. Gallun FJP, Lewis MSP, Folmer RLP, Hutter MMS, Papesh MAP, Belding HBS, Leek MRP. Chronic effects of exposure to high-intensity blasts: Results of tests of central auditory processing. *Journal of Rehabilitation Research and Development* 2016; 53(6): 705-720.
16. Jedlicka D, Zhen L. PTSD is associated with self-perceived hearing handicap: An evaluation of comorbidities in Veterans with normal audiometric thresholds. *Journal of the American Academy Audiology* 2023; 34(9-10): 183-191.

17. Vander Werff KR, Rieger B. Auditory and cognitive behavioral performance deficits and symptom reporting in postconcussion syndrome following mild traumatic brain injury. *Journal of Speech Language and Hearing Research* 2019; 62(7): 2501-2518.

Waddell K, Grewal E, Dass R, Ciurea P, Whitelaw H, Goodale G, Bain T, Phelps A, Wilson MG. Rapid evidence profile #83: Diagnosing central auditory processing disorder. Hamilton: McMaster Health Forum, 5 November 2024.

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