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REVIEW

Communication, academic and social outcomes of childhood cancer survivors with hearing loss: A systematic review

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Abstract

Many children treated for cancer are at risk of hearing loss. However, little is known about how hearing loss impacts their communication, academic and social outcomes. To examine the impact, this systematic review aimed to synthesise and appraise quantitative and qualitative studies reporting on (i) participants with hearing loss treated with platinum-based chemotherapy or cranial radiotherapy during childhood; and (ii) speech, language, academic performance, or social participation findings. Systematic database searches yielded 23 relevant articles that were analysed using narrative synthesis. Difficulties were reported for some but not all communication, academic and social aspects; however, a quality assessment using Grading of Recommendations Assessment, Development and Evaluation (GRADE) revealed low to very low certainty in the findings. Future research should aim to increase the quality of the research evidence and explore how multidisciplinary services can provide evidence-based support for childhood cancer survivors with competing hearing, communication, and social difficulties.

KEYWORDS
cancer survivors, child, communication, hearing loss, quality of life

1 | INTRODUCTION

Approximately one-third of childhood cancer survivors (CCS) experience a chronic condition that is severe, disabling, or life-threatening due to cancer or treatment.[1,2] For CCS treated with platinum-based chemotherapy or cranial radiotherapy (CRT), this may include a risk of treatment-induced hearing loss (HL).[3–6] This type of HL is typically bilateral, resulting from irreversible and often progressive damage to structures within the inner ear.[7–9] While the prevalence of treatment-induced HL is unclear, a 2016 Cochrane Review found that studies reported between 1.7% and 90.1% of CCS have some degree of HL after platinum chemotherapy.[10]

As CCS often experience HL during critical stages of childhood development, they may be vulnerable to life-long effects on quality of life.[11–13] Knowledge about the potential impacts of HL on CCS is largely based on evidence from children without cancer, principally children born with HL,[5,14–17] including children with unilateral or mild–moderate HL.[18–20] Significant HL in the general paediatric population can impact speech and language development,[21–24] and can lead to poor educational and occupational outcomes[25,26] and delayed socio-emotional skills.[27] However, this evidence may not accurately elucidate the support needs of CCS with treatment-induced HL who likely had normal hearing before cancer treatment. CCS often experience physical, cognitive and psychological late effects

Abbreviations: CCS, childhood cancer survivors; CNS, central nervous system; CRT, cranial radiotherapy; GRADE, Grading of Recommendations for Assessment, Development and Evaluation; HL, hearing loss; JBI, Joanna Briggs Institute; OSF, Open Science Framework; PEO, Population, Exposure and Outcome; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analyses.

of treatment, which could compound or coincide with the impacts of treatment-induced HL.[28–31] CCS may also experience barriers to timely diagnosis and effective audiological management due to medical issues,[32–34] and the emergence or worsening of HL years after cancer treatment.[4,35,36]

Greater clarity about HL impacts specific to CCS can help holistically understand the support needs after cancer. In 2019, a systematic review reported adults with treatment-induced HL or tinnitus were more likely to have lower quality of life than other adults with cancer.[12] Systematic reviews have also demonstrated some CCS experience greater communication, academic and social barriers than children without cancer.[32,37–41] However, no literature review has collated or evaluated evidence about the outcomes of CCS with treatment-induced HL.

Research highlighting the current challenges faced by CCS with HL can help researchers and clinicians to evaluate the effectiveness of current management practices. Existing recommendations state that children and young adults at risk of treatment-induced HL should have audiological testing before, during and after cancer treatment,[5,14,42] and be referred to audiologists and speech-language pathologists as clinically indicated.[16,42,43] However, once treatment-induced HL is identified, sparse high-quality empirical evidence is available to support clinicians and families to manage HL and the corresponding impacts on everyday functioning. For example, the International Guideline Harmonization Group developed recommendations about audiological monitoring of CCS after a systematic database search, and located no primary studies that examine the rehabilitation needs of CCS with HL.[5]

Therefore, the present systematic review aimed to identify, critically evaluate and synthesise studies about individuals with HL after paediatric cancer treatment with platinum chemotherapy, CRT or both. The synthesis aimed to identify the impacts of treatment-induced HL on the speech, language, academic performance and social participation of CCS.

Based on evidence from children with HL unrelated to cancer treatment[22,27,44] and the negative impact of late effects on CCS,[11,32,41] it was hypothesised that CCS with treatment-induced HL would experience ongoing communication difficulties, poorer academic performance and social participation limitations. Communication was conceptualised as (i) speech: the production of sounds while talking; and (2) language: the use (expressive language) and understanding (receptive language) of words and sentences while speaking, listening, reading or writing.

2 | METHODS

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines,[45] and was guided by the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis.[46] On 14 January 2022, the research protocol was registered with the Open Science Framework (OSF) at https://doi.org/10.17605/OSF.IO/HTPK2. The research team encompassed two speech pathologists, one audiologist and an honours student completing their speech pathology degree.

TABLE 1 Inclusion criteria.

PEO element	Inclusion criteria
Population	Participants aged under 18 years when treated for any type of cancer with cranial radiotherapy, platinum chemotherapy or both. The age range may exceed 18 years if the average age in the study fell below this threshold.
Exposure	Any degree of bilateral or unilateral hearing loss (HL) detected with pure tone or speech audiometry, reported by participants, or implied within the study (e.g., reported use of hearing aids).
Outcomes	Reported findings on one or more of the following impacts of HL: • speech production • expressive or receptive language • academic performance • social participation
Data types	Quantitative findings could be reported using primary or secondary outcome measures.Qualitative findings were considered themes, concepts or experiences inductively identified.

2.1 | Eligibility criteria

A Population, Exposure and Outcomes (PEO) format was selected for the search query, as recommended for reviews investigating the association between risk factors and outcomes.[47] Quantitative and qualitative studies were eligible for inclusion if they met the PEO elements, as outlined in Table 1. Conference abstracts, literature reviews and non-English language studies were excluded.

2.2 | Information sources and search strategy

To identify relevant studies, systematic database searches were conducted on 20 January 2022 using Medline via OVIDSP (1946–2022), Embase via OVIDSP (1947–2022) and Web of Science via Clarivate Analytics (1900–2022). The searches used keywords and database-specific subject headings around the main concepts 'child' and ('platinum chemotherapy' or 'cranial radiotherapy') and 'hearing loss' and ('speech' or 'language' or 'education' or 'social interaction'). The search terms were finalised after initial review by an independent research librarian and presented in Supplemental Table S1. The search entailed no restriction on publication date. Results were confined to journal articles.

Additionally, the first author conducted a Google Scholar Advanced Search on 20 February 2022. This entailed the following: all of the words 'child, hearing loss, cancer' and at least one of the words 'speech,

language, education, academic, social, impact, experience'. Keywords could be 'anywhere in the article'. No date or publication type limitations were applied. Only the first 200 results sorted 'by relevance' were extracted as this optimises selectivity of systematic reviews when used in combination with Medline, Embase and Web of Science.[48]

Between 24 February and 28 March 2022, the first author also hand-searched for studies by screening the reference lists of (i) core systematic reviews yielded by the database search results; and (ii) studies included in this review.

2.3 | Study selection

Citation details from the database, Google Scholar and reference list search results were exported into the reference manager *EndNote X8* (https://endnote.com/) and then the systematic review management software *Covidence* (https://www.covidence.org). Duplicates were removed via these programs.

Two reviewers independently assessed studies against the eligibility criteria upon title and abstract screening with full-text verification. Disagreements were discussed at regular meetings between the reviewers until consensus. This included a decision to exclude articles about acoustic schwannomas, tumours that can cause HL because they are located on the vestibulocochlear nerve,[49] whereas this review examined HL caused by cancer treatment.

2.4 | Data collection

Relevant data were extracted from all eligible studies using a customised template, including the research methodology and each PEO element (see Supplemental Table S2). The reviewers independently extracted data from 20% of studies. As 80% agreement was reached between reviewers, the first author extracted the remaining studies with consensus from the remaining authors.

2.5 | Quality within individual studies

The methodological quality of each study was evaluated using the JBI critical appraisal checklists (https://jbi.global/critical-appraisal-tools) to accommodate different research designs[50] and compare to previous research.[51] The two reviewers independently rated each checklist item as present, absent or unclear. Disagreements were discussed between the reviewers until consensus.

2.6 | Quality across studies

Evidence quality was assessed using Grading of Recommendations for Assessment, Development and Evaluation (GRADE).[52] The first author evaluated the level of concern (none, serious, very serious) for each GRADE element (risk of bias, imprecision, inconsistency, indirectness, publication bias) for all studies and each outcome domain (speech, language, academic performance, social participation). These gradings were used to evaluate the certainty of evidence (very low, low, moderate, high) for each outcome domain. Twenty percent of the ratings were verified by the research team to confirm rating consistency.

2.7 | Evidence synthesis

Because of heterogeneous data and methodologies, the extracted data were analysed using narrative synthesis,[53] with guidance from mixed method synthesis[54,55] and Synthesis without Meta-analysis in Systematic Reviews.[56] All critically appraised studies were included. Narrative descriptions and tables were produced for each outcome domain with the details about the study characteristics and each PEO element (see Supplemental Table S3). While planned at pre-registration to combine speech and language into 'communication', separate narrative syntheses were developed because greater than or equal to four studies reported on each outcome. Within the narrative description of each outcome domain, similar outcome measures were grouped together to identify the types of impacts HL had on CCS.

3 | RESULTS

3.1 | Study selection and characteristics

The search strategies generated 1437 search results, including 57 studies eligible to screen at full text (see Figure 1 for a PRISMA flow diagram). Of these, 23 studies met the eligibility criteria. There were four studies examining speech, eight for language, 13 for academic performance and 15 for social participation. Overall, 15 studies reported on more than one outcome domain (see Table 2).

The included studies comprised 20 quantitative designs (one case–control, four case series, seven cohort, eight cross-sectional) and three qualitative designs.

3.2 | Participant characteristics

3.2.1 | Population

The studies contained a total of 26,367 participants, ranging from five to 10,488 (median = 110) per study. This involved 25,437 CCS (96.5% of sample) and 930 controls without a previous cancer diagnosis (3.5%). The age of CCS ranged from 0 to 21 years at cancer diagnosis or treatment (range presented in 17/23 studies; 73.9%). CCS were aged 3–74 at study participation (range presented in 17/23 studies; 73.9%).

3.2.2 | Hearing loss

Two of the 23 studies (8.7%) did not report the number of CCS with HL.[57,58] Across the remaining studies, 1342 out of 19,503 (6.9%) cancer patients had HL ranging from unilateral, bilateral and mild to profound. Most studies assessed hearing status using

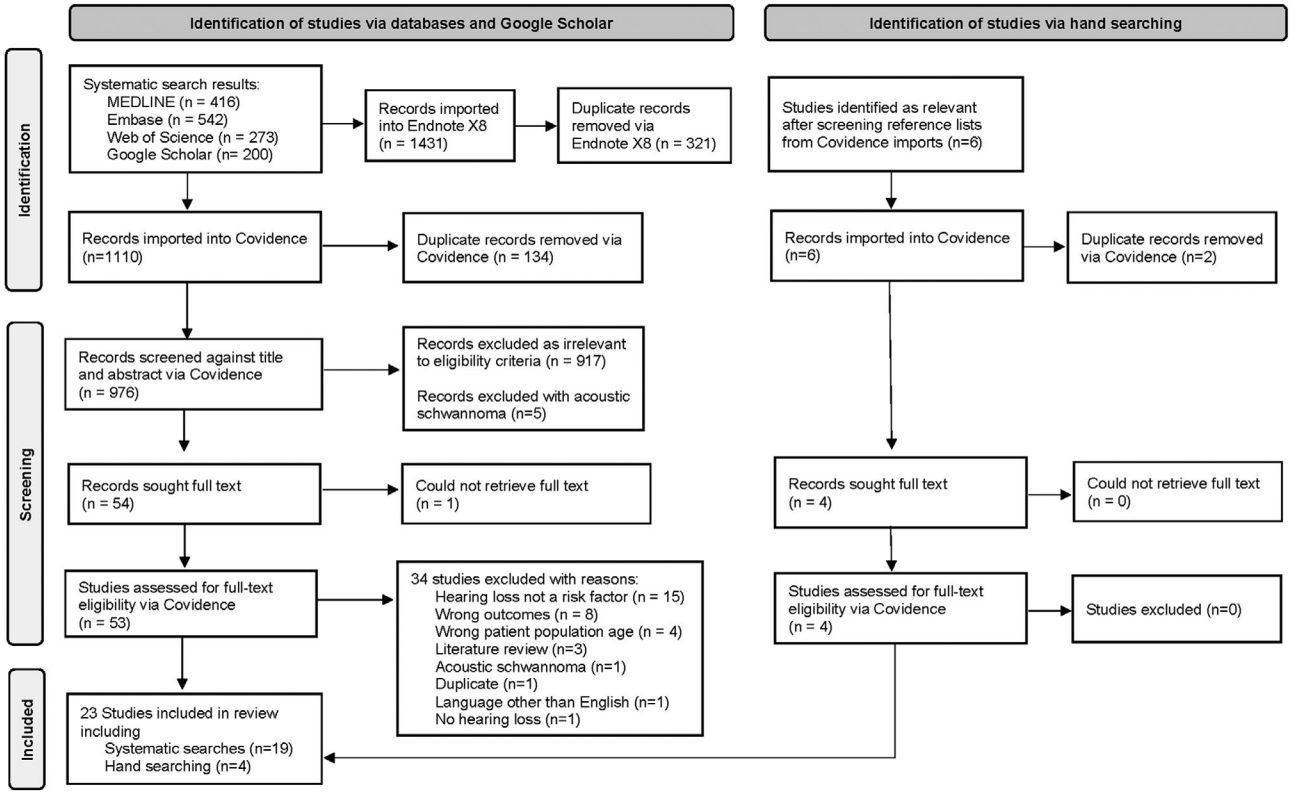

FIGURE 1 Flow diagram shows study selection. *Template adapted from page and colleagues.*[45]

audiometric testing (15/23; 65.2%)[59–72] or parent/patient report (6/23; 26.1%).[57,58,73–76]

3.2.3 | Cancer diagnosis and treatment

All except two studies (21/23; 91.3%) described cancer types.[65,73] Of these, 12/21 (57.1%) included participants with either central nervous system (CNS) or non-CNS cancer types,[57,58,61,66,68–72,77–79] eight studies (8/21; 38.1%) included participants with only CNS cancer[59,60,62,64,67,74–76] and one (1/21; 4.8%) examined only non-CNS cancer (soft tissue sarcoma).[63]

For 13/23 studies (56.5%), most participants were within the survivorship phase of cancer,[57–59,63,65,66,71,72,74,76–79] while 10/23 studies (43.5%) corresponded with the after-hospital to outpatient phase.[60–62,64,67–70,73,75] No study included cancer inpatients.

Twenty-one studies described cancer treatment. Of these, two (2/21; 9.5%) mentioned platinum-based chemotherapy without CRT,[67,73] three (3/21; 14.3%) mentioned CRT without platinum-based chemotherapy,[57,58,63] and 16/21 (76.2%) mentioned both platinum-based chemotherapy and CRT.[59,60,62,64,66,68–72,74–79]

3.3 | Quality appraisal

Individual quality appraisal revealed six of 23 (26.1%) studies had fewer than 70% of the JBI checklist items for its research design (range = 20%–90%).[67–69,71,73,77] This included two of four (50.0%) studies on speech, which did not clearly report their results and participant recruitment.[67,73] Most studies about language (5/8; 62.5%)[60,62–64,74] and academic performance (11/13; 84.6%)[60,62,63,66,69–71,74–76,79] had methodological strengths when presenting clinical information, however, were limited by missing data due to incomplete participation or absent baseline measures. For social participation, four of 15 (26.7%) studies contained below 70% of the JBI elements.[67,68,71,77] See Table 2 for the individual JBI scores and Supplemental Table S4 for the JBI checklist responses of each study.

The GRADE quality assessment revealed very low certainty about the impacts of treatment-induced HL on the speech of CCS, and low certainty for language, academic performance and social participation (see Table 3). Primary concerns were that most studies had small sample sizes, significant variability in clinical and demographic characteristics of participants, and inconsistent outcome measures.

3.4 | Key impacts of hearing loss

The types of HL impact were identified for each outcome domain (see Table 4). For speech, findings were related to speech clarity. The impacts of language were examined for spoken language, written language (literacy) and perceived communication ability. Academic performance had three types of impact: level of education completed,

TABLE 2 Outcome domains and quality assessment of each included study.

	Citation details	Country	Research design	Speech	Language	Academic performance	Social participation	JBI quality assessment score
1	Al-Khatib et al. (2010)[70]	Canada	Case series	X		X		8/10 (80.0%)
2	Baum (2008)[67]	United States	Cross-sectional	X			X	4/8 (50.0%)
3	Brinkman et al. (2015)[66]	United States	Cross-sectional			X	X	7/8 (87.5%)
4	Brinkman et al. (2016)[58]	United States	Cohort				X	8/11 (72.7%)
5	Clemens et al. (2017)[71]	Netherlands	Cohort			X	X	7/11 (63.6%)
6	Einar-Jon et al. (2010)[72]	Iceland	Case series				X	9/10 (90.0%)
7	Ellenberg et al. (2009)[77]	United States	Cohort			X	X	7/11 (63.6%)
8	Frobisher et al. (2017)[78]	United Kingdom	Cross-sectional				X	7/8 (87.5%)
9	Gurney et al. (2007)[74]	United States	Cross-sectional		X	X	X	7/8 (87.5%)
10	Heitzer et al. (2020)[59]	United States	Cross-sectional		X		X	7/8 (87.5%)
11	Khan et al. (2020)[65]	United States	Qualitative			X	X	9/10 (90.0%)
12	Kruseova et al. (2020)[76]	Czech Republic	Cohort			X		10/11 (90.9%)
13	Olivier et al. (2019)[64]	United States, Australia and Canada	Cohort		X			10/11 (90.9%)
14	Olsson et al. (2020)[63]	United States	Case-control		X	X	X	7/10 (70.0%)
15	Orgel et al. (2016)[60]	United States	Cohort		X	X		9/11 (81.8%)
16	Rajput et al. (2020)[68]	United Kingdom	Cross-sectional		X		X	5/8 (62.5%)
17	Schreiber et al. (2014)[62]	United States, Australia and Canada	Cohort		X	X		9/11 (81.8%)
18	Schulte et al. (2018)[57]	United States	Cross-sectional				X	7/8 (87.5%)
19	Schulz et al. (2020)[61]	United States	Qualitative	X			X	7/10 (70.0%)
20	Skinner et al. (1990)[69]	United Kingdom	Case series			X		5/10 (50.0%)
21	Smith (2012)[73]	United States	Case series	X	X			2/10 (20.0%)
22	Vanclooster et al. (2021)[75]	Belgium	Qualitative			X		9/10 (90.0%)
23	Weiss et al. (2019)[79]	Switzerland	Cross-sectional			X	X	7/8 (87.5%)

TABLE 3 GRADE certainty ratings for each outcome domain.

		Speech	Language	Academic performance	Social participation
GRADE ratings	Risk of bias	Very serious concerns	Serious concerns	Serious concerns	Serious concerns
	Imprecision	Very serious concerns	Serious concerns	Serious concerns	Very serious concerns
	Inconsistency	Serious concerns	Serious concerns	Serious concerns	Serious concerns
	Indirectness	Serious concerns	Serious concerns	Serious concerns	Serious concerns
	Publication bias	None detected	None detected	None detected	None detected
	Overall certainty	**Very low**	**Low**	**Low**	**Low**

Abbreviation: GRADE, Grading of Recommendations for Assessment, Development and Evaluation.

perceived school functioning and mathematics performance. For social participation, the impacts examined were employment status, peer interactions and social well-being.

Most studies (19/23; 82.6%) measured the outcomes using a parent or self-completed questionnaire.[57,59,61,63,65–75,77,79] Five studies (5/21; 21.7%) assessed outcomes using standardised test.[59,60,62–64] See Supplemental Table S5 for details about each individual study.

3.4.1 | Outcome domain 1: Speech

Four studies examined the speech clarity of CCS with treatment-induced HL using a survey or interview question completed by the child or their parent after cancer treatment.[61,67,70,73] Two of these studies (2/4; 50.0%) did not report perceived speech changes for CCS.[61,67] The other two studies (2/4; 50.0%) reported speech changes without

TABLE 4 Study characteristics grouped by outcome domain.

		Population					Exposure	Comparison	Outcomes
	Research designs	Number of participants	Age range in years[a]	Cancer type[b]	Cancer stage	Hearing loss	Cancer treatment[c]	Groups for analysis	Types ofimpact examined (# studies)
Speech	Total 4 studies including: 2 case series 1 cross-sectional 1 qualitative	Total: 59 Range: 8–22 per study	Diagnosis: 0—17 (from 4/4 studies) Study: 5—22 (from 3/4 studies)	3× varied 0× CNS 1× NR	After hospital to outpatient: 4/4 studies	Total with HL: 24 people Including: Any HL: 3 studies Significant HL: 1 study	NR ×1 Chemo ×2 Mixed ×1	NIL NB: HL ($n = 1$) + non-HL ($n = 15$) in one cross-sectional study. No group analysis as too few participants	(a) Speech clarity (4)
Language	Total 8 studies including: - 3 cross-sectional - 3 cohort - 1 case–control - 1 case series	Total: 1240 Range: 8–260 per study	Diagnosis: 0—21 (from 8/8 studies) Study: 5—42 (from 6/8 studies)	1× varied 5× CNS 1× NR 1× non-CNS	After hospital to outpatient: 5/8 studies Survivorship: 3/8 studies	Total with HL: 263 people Including Any HL: 5 studies Significant HL: 3 studies	Chemo ×1 Mixed ×6 CRT ×1	HL ($n = 255$) + non-HL ($n = 628$) across 7 studies Survivors ($n = 150$) + community controls (n = 499) in 1 study NIL in 1 study	(a) Comprehension of spoken language (3) (b) Written language: reading (4 studies) and writing (1) (c) Perceived communication ability (2)
Education	Total 13 studies including: 5 cohort, 3 cross-sectional, 2 case series, 2 qualitative, 1 case control	Total: 2212 survivors Range: 5–700 per study	Diagnosis: 0—20 (from 10/13 studies) Study: 3—52 (from 10/13 studies)	6× varied 5× CNS 1× NR 1× non-CNS	After hospital to outpatient: 5/13 studies Survivorship: 8/13 studies	Total with HL: 594 people Including: Any HL: 9 studies Significant HL: 4 studies	Chemo ×1 Mixed ×11 NR ×1	HL ($n = 255$) + non-HL ($n = 628$) across 11 studies Survivors ($n = 150$) + community controls ($n = 499$) in 1 study NIL in 2 studies	(a) Education level (4) (b) Perceived school functioning (6) (c) Mathematics performance (3)
Social	Total 15 studies including:- 8 cross-sectional - 3 cohort - 2 qualitative - 1 case control - 1 case series	Total: 19,691 survivors Range: 13–10, 267 per study	Diagnosis: 0—20 (from 12/15 studies) Study: 5—74 (from 14/15 studies)	11× varied 2× CNS 1× NR 1× non-CNS	After hospitalto outpatient: 3/15 studies Survivorship: 12/15 studies	Total with HL: 1174 people (from 14/15 studies) Including: Any HL: 13 studies Significant HL: 2 studies	Chemo ×1 Mixed ×12 NR ×2 CRT ×1	HL ($n = 1549$) + non-HL ($n = 24077$) across 9 studies Survivors ($n = 7690$) + community or sibling controls ($n = 1357$) across 3 studies CNS ($n = 1770$) + non-CNS ($n = 8116$) across 3 studies CRT ($n = 2770$) + non-CRT ($n = 1123$) in 1 study NIL in 4 studies	(a) Employment status (5) (b) Peer interactions and social well-being (11)

Abbreviations: CNS, central nervous system (brain and spinal cord); CRT, cranial radiotherapy; HL, hearing loss; NR, not reported.

[a]Age: If range was not reported, the age range was calculated using the mean age and standard deviation (if provided).

[b]Cancer types considered: CNS and non-CNS; Varied refers to inclusion of study participants with both CNS and non-CNS.

[c]Cancer treatment: data were only extracted about platinum-based chemotherapy and CRT; Chemo = mentioned platinum-based chemotherapy only; Mixed = mentioned inclusion of participants with platinum-based chemotherapy and/or CRT; CRT = mentioned CRT but not chemotherapy with platinum compounds.

specifying the number of CCS affected: Smith[73(p10)] mentioned 'two or more' participants had difficulties saying words clearly, and Al-Khatib et al.[70] did not separate the speech and school performance findings. Speech outcomes were not compared between participants with and without HL.

3.4.2 | Outcome domain 2: Language

Three studies examined CCS' understanding of spoken language using composite scores of a standardised neurocognitive test.[59,60,63] All three studies (3/3; 100.0%) found that CCS with and without treatment-induced HL had statistically similar overall verbal comprehension scores. Performance on specific aspects of spoken language varied. For example, in Orgel et al.,[60] CCS with significant HL were more likely to have difficulties with vocabulary and word reasoning than those with normal hearing.

Five studies examined reading ability using a standardised neurocognitive test.[60,62–64,74] Of these, four (4/5; 80.0%) reported CCS with HL had significantly greater difficulties than those with normal hearing.[60,62,64,74] These studies involved CCS less than 5 years after CNS cancer diagnosis. The study (1/5; 20.0%) that did not detect a significant relationship between HL and poor reading performance involved CCS with an average of 25 years after cancer diagnosis.[63]

One study reported on writing ability using a parent-completed questionnaire, detecting no significant difference in the frequency of writing issues between CCS with and without HL.[74]

Two studies examined changes in language via its impact on communication ability as perceived by CCS or their parents.[68,73] In Rajput et al.,[68] parents were significantly more likely to report concerns about their child's communication if their child had HL. In the study by Smith,[73] eight school-aged CCS with treatment-induced HL rated communicating easily or very easily.

3.4.3 | Outcome domain 3: Academic performance

Four studies compared the level of education achieved between CCS with and without HL.[66,71,76,77] Of these, three studies (3/4; 75.0%) found no significant differences in the level of education achieved by CCS with and without HL.[66,71,76] The fourth study (1/4; 25.0%) noted an indirect relationship: CCS were more likely to experience neurocognitive impairments, which were significantly associated with lower educational attainment.[77]

Six studies examined the self- or parent-perceived school functioning of CCS with treatment-induced HL.[65,69,70,74,75,79] Of these, four (4/6; 66.7%) described HL as a factor associated with changes in performance at school.[65,69,70,75] For example, in Skinner et al.,[69] one student reportedly had difficulties concentrating in the classroom due to HL after cancer treatment. The other two studies (2/6; 33.3%) compared self- or parent-perceived school functioning between CCS with and without treatment-induced HL.[74,79] For these studies, HL was significantly associated with poorer perceived school functioning for CCS in Gurney et al.,[74] which included only CNS-type cancers, but not Weiss et al.[79] which explored any cancer type.

Three studies used a standardised neurocognitive test of achievement to measure academic performance in maths.[60,62,63] This involved one study (1/3; 33.3%) with participants 10 or more years after cancer treatment in which CCS with HL had significantly poorer mathematics scores than CCS with normal hearing.[63] The other two studies (2/3; 66.7%) examined short-term outcomes, identifying no significant difference in mathematics ability between these groups.[60,62]

3.4.4 | Outcome domain 4: Social participation

Five studies examined the long-term impact of HL on patient-reported employment status.[63,66,71,77,78] Of these, one (1/5; 20.0%) found that CCS with HL were more likely to be unable to work for health reasons than those without HL.[78] Another study (1/5; 20.0%) identified an indirect relationship between HL and employment: adult CCS were more likely to experience impaired task efficiency in the workplace, which was significantly associated with less than full-time employment.[77]

Seven studies compared the peer interactions and social well-being of CCS with and without HL using a disability or quality-of-life questionnaire.[57–59,68,74,78,79] Most studies (6/7; 85.7%) reported that CCS with HL were perceived to have significantly poorer relationships or peer acceptance.[57,58,68,74,78,79] Of these, Weiss et al.[79] found only CNS cancer survivors had poorer relationships, while Brinkman et al.[58] only detected poorer social well-being for CCS not treated with CRT.

Four studies examining social functioning did not compare outcomes between CCS with and without treatment-induced HL.[61,65,67,72] All four studies identified that CCS with HL previously experienced negative social experiences because of HL or hearing aids (e.g., feeling disconnected or fearing bullying).

4 | DISCUSSION

This systematic review aimed to identify the impacts of treatment-induced HL on speech, language, academic performance and social participation for individuals with a history of paediatric cancer treatment. Within 23 studies reporting on these outcomes, the more consistent findings suggested that treatment-induced HL may be associated with challenges in reading ability and peer interactions for CCS. This is congruent with evidence about children with HL unrelated to cancer who are vulnerable to poorer quality of life and may require additional literacy support.[21,23] Likewise, adolescent and young adult brain tumour survivors and their caregivers identified social and cognitive difficulties, often related to school performance, as priority long-term issues.[32]

Surprisingly, studies did not consistently reveal impacts on verbal comprehension, academic attainment or employment status because of treatment-induced HL. This contrasts with considerable research from the wider paediatric population demonstrating that HL can delay

speech and language development[20–24,27] and contribute to academic difficulties.[25,26] This incongruency might reflect a difference between the impacts of acquired HL after cancer and congenital HL on which most research is based. With a range of differing physical, psychological and environmental circumstances,[24,34,75] factors other than the presence of treatment-induced HL may have a more pronounced impact on CCS. For example, children with CNS cancers and leukaemia already have an increased risk of communication, academic and occupational difficulties.[37–40] Alternatively, it is possible that studies contained too few CCS with HL for measured outcomes to present as statistically significant.[80]

Because included studies were heterogeneous and lacked baseline measures, this review cannot evaluate the influence of confounding factors, such as access to support services or hearing intervention, age at cancer diagnosis and type or intensity of cancer treatment.[6,31,41] However, more studies about children with CNS tumours reported significantly poorer performance in reading, perceived school functioning and peer interactions than studies encompassing any type of cancer. This may reflect that CNS cancer survivors have higher rates of neurocognitive difficulties, which are significantly associated with poorer academic and social outcomes.[29,33] Additionally, neurocognitive difficulties may be more prevalent in CCS with treatment-induced HL compared with CCS without HL.[30,59,60,62–64] Future large and well-controlled studies comparing hearing acuity, as well as communication and neurocognitive outcomes both before and at more than one time point after cancer treatment, would be ideal to clarify the additional short- and long-term impact of treatment-induced HL for CCS. Such studies, however, must also be pragmatic and consider the extensive needs of these children and families around the time of cancer diagnosis and treatment. Recent expert guidelines recommend that audiometric testing between 1000 and 8000 Hz be done no later than the end of treatment and annually for children younger than 6 years of age, every other year for children between 6 and 12 years of age, and every 5 years for teenagers and young adults.[5] In countries where a Universal Newborn Hearing Screening programme is in place, studies should attempt to include the outcomes of such screening and any other hearing, communication or cognitive tests as baseline measures before cancer treatment.

Given inconsistent and low-certainty evidence, no definitive conclusions can be drawn about the impacts of treatment-induced HL. However, the findings reiterate previous accounts based on the general paediatric population[5,10,14,15] that some CCS may experience competing hearing, communication, academic and social challenges. This emphasises the importance of multidisciplinary care for CCS at risk of treatment-induced HL who are already vulnerable to other physical, cognitive and psychological late effects of cancer treatment.[28,31] In addition to audiologists and the medical team, this may include speech-language pathologists, teachers, psychologists, physiotherapists and occupational therapists who can have important roles in monitoring for and managing the impacts of cancer and cancer treatment, including HL, throughout different phases of cancer.

This review suggests that there is a need for greater consistency and use of outcome-specific assessment tools for CCS with treatment-induced HL, especially around speech and language. Current practice recommends speech production be measured in conversation and single words alongside a combination of formal and informal measures for expressive and receptive language.[20,81,82] However, most measures of speech in this review relied on parent report, and no study comprehensively assessed language-specific skills.

Further research must be prioritised in this area, in consultation with CCS, their families and multidisciplinary providers involved in their communication, academic and social care. Selecting and more consistently using reliable assessment tools will help researchers and clinicians identify an individual's support needs after cancer treatment and monitor the effectiveness of hearing or communication intervention. Moreover, further work is required to determine the types of services already provided to CCS and whether further specialised support would help manage the potential impacts of treatment-induced HL. This can guide research into the effectiveness and feasibility of current HL management strategies for CCS.

5 | CONCLUSION

It was initially hypothesised that CCS with treatment-induced HL would experience difficulties across speech production, expressive and receptive language, academic performance and social participation. In this review, poor functioning for CCS with treatment-induced HL was described for some but not all domains. Despite low-quality evidence, the emerging findings highlight the potential for CCS to experience a diverse range of challenges after cancer treatment and therefore the value of access to long-term multidisciplinary support to promote the quality of life for cancer patients at risk of treatment-induced HL. Future research will require increased consistency in the selection and application of the measures used with this population.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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