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ORIGINAL ARTICLE

A cross-sectional survey of non-specialist Australian audio-vestibular clinical practice for traumatic brain injury and rehabilitation

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Abstract

Objective: This study explored non-specialist audiological clinical practice in the context of traumatic brain injury (TBI), and whether such practices incorporated considerations of TBI-related complexities pertaining to identification, diagnosis and management of associated auditory and vestibular disturbances.
Design: A cross-sectional online survey exploring clinical practice, TBI-related training and information provision was distributed to audiologists across Australia via Audiology Australia and social media. Fifty audiologists, 80% female and 20% male, participated in this study. Years of professional practice ranged from new graduate to more than 20 years of experience.
Results: Clear gaps of accuracy in knowledge and practice across all survey domains relating to the identification, diagnosis and management of patients with auditory and/or vestibular deficits following TBI were evident. Further, of the surveyed audiologists working in auditory and vestibular settings, 91% and 86%, respectively, reported not receiving professional development for the diagnosis and management of post-traumatic audio-vestibular deficits.
Conclusion: Inadequate resources, equipment availability and TBI-related training may have contributed to the gaps in service provision, influencing audiological management of patients with TBI. A tailored TBI approach to identification, diagnosis and management of post-traumatic auditory and vestibular disturbances is needed.

Keywords: traumatic brain injury; audiology; hearing; balance; assessment; rehabilitation

Introduction

Traumatic brain injury (TBI), a leading cause of morbidity and mortality worldwide, represents a significant socioeconomic problem (Levin, Shum, & Chan, 2014; Maas et al., 2015; Wee, Yang, Lee, Cao, & Chong, 2016; World Health Organization, 2014). In the developed world, the annual incidence of TBI is estimated between 99 to 295 per 100,000 people (Bruns & Hauser, 2003; Doan et al., 2016; Nguyen et al., 2016; Pozzato, Tate, Rosenkoetter, & Cameron, 2019; World Health Organization, 2014), with a projected annual global burden between $98 million USD to $302 million USD (Humphreys, Wood, Phillips, & Macey, 2013). TBI has a highly heterogenous set of long-term consequences, arising from factors relating to its aetiology, pathology, mechanism of damage (i.e., penetrating vs non-penetrating, blast vs non-blast-related) and severity (i.e., mild, moderate or severe) (Maas, 2016). While blast-related TBI carries significant implications pertaining to post-traumatic deficits and rehabilitation outcomes (Fausti, Wilmington, Gallun, Myers, & Henry, 2009), the incidence of blast-related TBI in the Australian context is unclear. However, TBI incidence rates in UK combat personnel have been reported at 9.0 (95% CI: 8.3–9.8) per 100, inclusive of blast and non-blast-related injury (Rona et al., 2012). Civilian practitioners (e.g., audiologists) are hence less likely to encounter patients following blast-related injury, particularly in non-specialised clinical audiology settings.

Non-blast-related post-traumatic disturbances, not restricted to severe cases, encompass a range of cognitive (e.g., memory, attention), physical (e.g., headaches), sensory (e.g., vision, hearing, olfaction) and emotional (e.g., depression) disturbances (Munjal, Panda, & Pathak, 2010a, 2010b; Roozenbeek, Maas, & Menon, 2013). The severity classification of TBI (i.e., mild, moderate, severe) is predicated on the duration of loss of consciousness (Glasgow Coma Score), the change in mental status (post-traumatic amnesia) and imaging results (Cassidy et al., 2004; Chen et al., 2018). In acquired brain injury rehabilitation centres (i.e., specialist rehabilitation units) identification and management of audio-vestibular post-traumatic disturbances, in moderate and severe cases, may be hindered or delayed given practitioners' focus on investigating other more serious injuries (Munjal et al., 2010b; Wood & Worthington, 2017). In mild TBI, on the other hand, identification and diagnosis is hindered by the reduced likelihood of patients presenting to acute clinical settings (Nguyen et al., 2016). Hence, patients with post-traumatic audio-vestibular disturbances secondary to mild TBI have higher likelihood of presenting to non-specialist audiological settings.

From an audiological perspective, a substantial proportion of retrospective studies provide strong evidence of auditory and vestibular deficits following non-blast-related TBI (Balatsouras et al., 2017; Bergemalm & Borg, 2001; Jury & Flynn, 2001; Munjal et al., 2010a, 2010b). Despite the TBI-related pathophysiology and the probability of both central and peripheral audio-vestibular system involvement (Alhilali, Yaeger, Collins, & Fakhran, 2014; Arshad et al., 2017; Marcus et al., 2019), this paper centres on audio-vestibular periphery for two reasons: 1) the survey was designed to explore the typical Australian audiological practice; and 2) patients with peripheral system disorders are reported to have better rehabilitation outcomes (Kolev & Sergeeva, 2016; Kushner, 1998). Our recent systematic reviews exploring the frequency of occurrence of peripheral auditory dysfunction (Šarkić, Douglas, & Simpson, 2019) and peripheral vestibular dysfunction (Šarkić et al., 2020) following TBI, revealed sensorineural hearing loss (SNHL) and benign paroxysmal positional vertigo (BPPV) as the most prevalent auditory and vestibular deficits at 37.3% and 39.7%, respectively. Notably, the prevalence rates that emerged from the two systematic reviews were subject to limitations of the included studies including retrospective data collection from non-acute settings.

Given the high prevalence of post-traumatic audio-vestibular deficits and the complex interaction of TBI associated comorbidities, patients with TBI represent a distinct and challenging patient population. While this paper does not explore audio-vestibular disturbances following mild TBI per se, the authors acknowledge the higher likelihood of these patients presenting to non-specialised audiological settings and therefore the importance of audiological identification, diagnosis and management in the context of TBI. Hence, an investigation of typical non-specialist audiological practice in the context of TBI is warranted. To the best of our knowledge, this is the first study to describe the typical non-specialist Australian audiology practice in the context of brain injury and rehabilitation.

In Australia, audiologists are university qualified and must hold a two-year postgraduate qualification in clinical audiology or equivalent (Hearing Care Industry Association, 2021). Australian audiologists are employed across the public, not-for-profit and private sectors with the majority employed in non-specialised (i.e., sole discipline) clinics where dispensing hearing aids, diagnostic testing and paediatric services constitute the primary areas of practice (Victorian Allied Health Workforce Research Program, 2018). While a mandated Audiological test battery in Australia does not exist, Audiology Australia provides guidance to audiology practices in selecting from several well-established and evidence-based tests, including that of a) otoscopy, b) tympanometry, c) pure tone audiometry (250Hz to 8000Hz, and d) speech discrimination testing (Audiology Australia, 2013, 2022). Under the Australian Government public health funding (Hearing Services Program), audiologists can claim payment for assessments and reviews that constitute otoscopy, pure tone audiometry and speech testing (Australian Government, 2022). In general, therefore, it is common practice to carry out a) otoscopy, b) tympanometry, c) pure tone audiometry (250Hz to 8000Hz) and d) speech discrimination testing, although some inconsistencies across clinics and states do occur. Similarly, Audiology Australia recommendations for balance assessments include a) otoscopy, b) videonystagmography, c) positional tests (including Dix Hallpike) and d) otolith function tests (Audiology Australia, 2013, 2022), again with variations across clinics.

Hence, the purpose of this study was to provide a preliminary description of the typical Australian non-specialist audiological practices in the context of TBI and whether such practices are holistic and consider the complexities of TBI-related comorbidities pertaining to diagnosis and management of this patient population.

Material and methods

Study design

Following ethical approval by the La Trobe University Human Research Ethics Committee (Ethics ID: HEC20240), a cross-sectional survey employing online distribution was conducted over the period of August to December 2020. The study complied to the principles outlined by the National Statement on Ethical Conduct in Human Research (2018).

Participants

Participants were recruited from the membership of Audiology Australia (AudA), the national professional body representing approximately 98% of practicing audiologists in Australia. At the time of the study, AudA had 3158 full members. Audiologists from both the public and private sector with a predominantly adult caseload were invited to participate in this study.

Material

An online survey encompassing both open-ended and multiple-choice questions was utilised for the purpose of this exploratory cross-sectional study. A secure web platform, Research Electronic Data Capture (REDCap), was applied to develop and manage the online survey (Harris et al., 2009), *See Appendix A*. The survey consisted of 35 questions, divided into four sections: section A (demographics); section B (training); section C (clinical practice) and section D (education and information provision). Given the exploratory nature of this survey, questions investigating audiologists' beliefs in their ability to practice in the context of TBI, and the support they received (i.e., training and/or professional development) were also included. The reasoning behind the inclusion of such questions was to gain insights into the current and typical audiological practice pertaining to the diagnosis and management of hearing and balance difficulties in the context of TBI. For instance, in Section C, participants who reported altering their typical non-specialised diagnostic test battery for patients with TBI were required to report their reasoning and to specify the choice of tests utilised.

The online survey was piloted with six practicing audiologists prior to advertising to potential participants. Minor amendments were made based on the feedback, including splitting some questions into smaller sections and simplifying the instructions.

Procedure

Following ethical clearance, a flyer containing information about the study with a link and Quick Response (QR) code to the online survey was distributed via AudA to their respective members.

Similarly, the flyer was shared via the first author's LinkedIn account where interested participants were able to scan the QR code and access the survey. Upon scanning the QR code or clicking on the link, participants were directed to an electronic participant information statement and asked to provide their consent. Only those participants who provided their consent were directed to section A (demographics), the first section of the survey, participants were otherwise directed to the end of the survey. All responses were recorded and managed in the REDCap online electronic data capture tools hosted at [La Trobe University], whether complete or incomplete, allowing the investigators to extract the data to Microsoft Excel (Microsoft Corporation, 2018) and SPSS (IBM Corp, 2019). The survey was distributed from August to December 2020, and it took approximately 15 min to complete.

Data analysis

Data were analysed using SPSS version 26 (IBM Corp, 2019). Descriptive statistics were performed to describe demographic variables in section A of the survey and any other closed questions across sections B to C. Open-ended questions were exported to Microsoft Excel (Microsoft Corporation, 2018) and analysed using content analysis. A summative approach (Hsieh & Shannon, 2005) was implemented to quantify in text content with the frequency of the most common responses pertaining to the respective survey questions counted and presented. Open-ended questions in sections B and C are reported below to further describe quantitative data. Section D contained only open-ended questions, the responses were summarised and compiled into common themes, coded, and analysed for frequency of occurrence. For example, responses containing information relating to handing out information to patients – for example, '*We have supplies of lots of patient handouts to take home for families' and 'Literature appropriate to the findings and care plan was provided'* were coded as 'patient handouts (PHO)'.

Results

Section A: demographics

A total of 50 audiologists, categorised by age into the following bands (20-30; n = 17; 31-40; n = 19; 41-50; n = 10; 51-60; n = 6; and 61-70; n = 1), responded to the survey. Eighty per cent of participants were female. Most respondents, 67%, were employed in metropolitan settings, 22% in regional and 11% in remote settings of Australia. Years of professional practice ranged from new graduates to over 20 years, **see** Table 1, with the highest proportion, 34%, in the less than five years band and the lowest proportion, 5%, in the new graduate band. The respondents reported a variety of employment settings, with the most common being rehabilitative private practice (34%), diagnostic private practice (23%) and rehabilitative public practice (12%). The most frequently reported caseloads were adult hearing diagnosis (23%), and adult hearing rehabilitation (23%), followed by paediatric hearing diagnosis (15%) and adult vestibular diagnosis (17%). The sample was reasonably representative of the general population of audiologists in terms of gender (80% female in this sample compared to 77% in the total AudA membership), type of employment (majority working in rehabilitation) and setting of employment (majority employed in metropolitan settings).

Section B: training

Sixty-one per cent of audiologists (n = 28) *in auditory diagnostic and/or rehabilitation clinical settings*, reported expecting a patient with TBI to present with a hearing loss, 30.4% (n = 14) were unsure and 8.7% (n = 4) did not expect post-traumatic hearing loss in patients with TBI. When asked whether diagnosis and management of hearing loss in patients with TBI differed to the typical clinical practice, 63% (n = 29) of audiologists agreed, 19.6% (n = 9) were unsure and

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Table 1. Demographic variables

Demographic Variables	Levels	N = 50	Percent
Gender			
	Male	10	20
	Female	40	80
Age			
	20–30	17	34
	31–40	19	38
	41–50	10	20
	51–60	3	6
	61–70	1	2
Years of Professional Practice			
	New graduate	5	10
	Less than five years	17	34
	Six to 10 years	10	20
	Eleven to 20 years	8	16
	More than 20 years	10	20
Clinical Settings			
	Acute Hospital	6	9
	Sub-acute/in-patient rehabilitation	1	2
	Out-patient/Day hospital	3	5
	Community health	5	8
	Diagnostic Private Practice	15	23
	Rehabilitative Private Practice	22	34
Clinical Settings (other)			
	Rehabilitative Public Practice	8	12
	University Clinic	3	5
	Cochlear Implant Centre	1	2
	Mobile Test Unit	1	2
Type of Caseload			
	Adult Hearing Diagnosis	38	23
	Adult Hearing Rehabilitation	38	23
	Paediatric Hearing Diagnosis	24	15
	Paediatric Hearing Rehabilitation	11	13
	Adult Vestibular Diagnosis	14	17
	Paediatric Vestibular Diagnosis	3	2
Type of Case load (other)		5	3
	Auditory Processing Disorder	2	1

(*Continued*)

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Table 1. (*Continued*)

Demographic Variables	Levels	N = 50	Percent
	Cochlear implant services	1	1
	Vestibular rehabilitation	1	1
	Tinnitus	1	1
Workplace Setting			
	Metropolitan	42	67
	Regional	14	22
	Remote	7	11

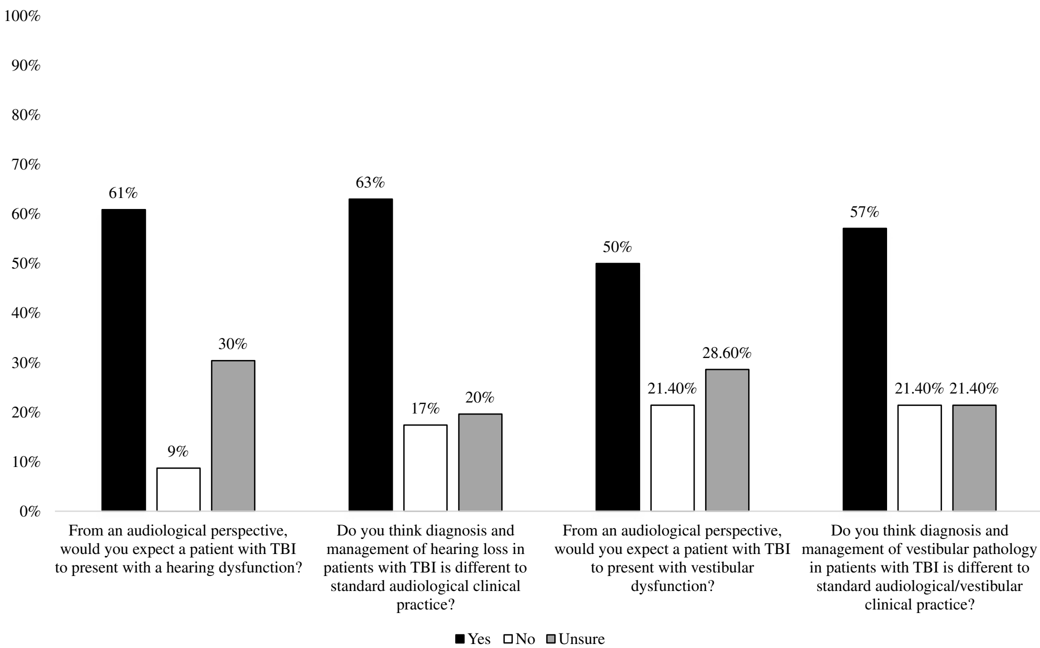

Figure 1. Expectation of auditory and vestibular deficits in patients with TBI as reported by clinical audiologists.
Note: Vestibular pathology questions were posed to audiologists working in vestibular settings.

17.4% (n = 8) disagreed. Of those audiologists who reported expecting a hearing loss in patients with TBI, 75% (n = 21) believed the nature of hearing loss could fall in any hearing loss category (i.e., sensorineural, conductive and mixed), 14.3% (n = 4) reported mixed hearing loss to be the most likely type of hearing loss, while 10.7% (n = 3) reported SNHL as the most likely type of loss, see Fig. 1.

Further, of those 14 audiologists employed in *vestibular clinical settings*, 57% (n = 8) believed the diagnosis and management of vestibular pathology secondary to TBI differed to the typical audiological/vestibular practice, the remainder of respondents either disagreed, 21.4% (n = 3), or were unsure, 21.4% (n = 3), see Fig. 1. Fifty per cent (n = 7) reported expecting patients with TBI to present with vestibular pathology, 28.6% (n = 4) were unsure and 21.4% (n = 3) did not expect post-traumatic vestibular pathology. When asked to list three types of the most expected vestibular pathology following TBI, seven participants responded of whom, three reported BPPV, two

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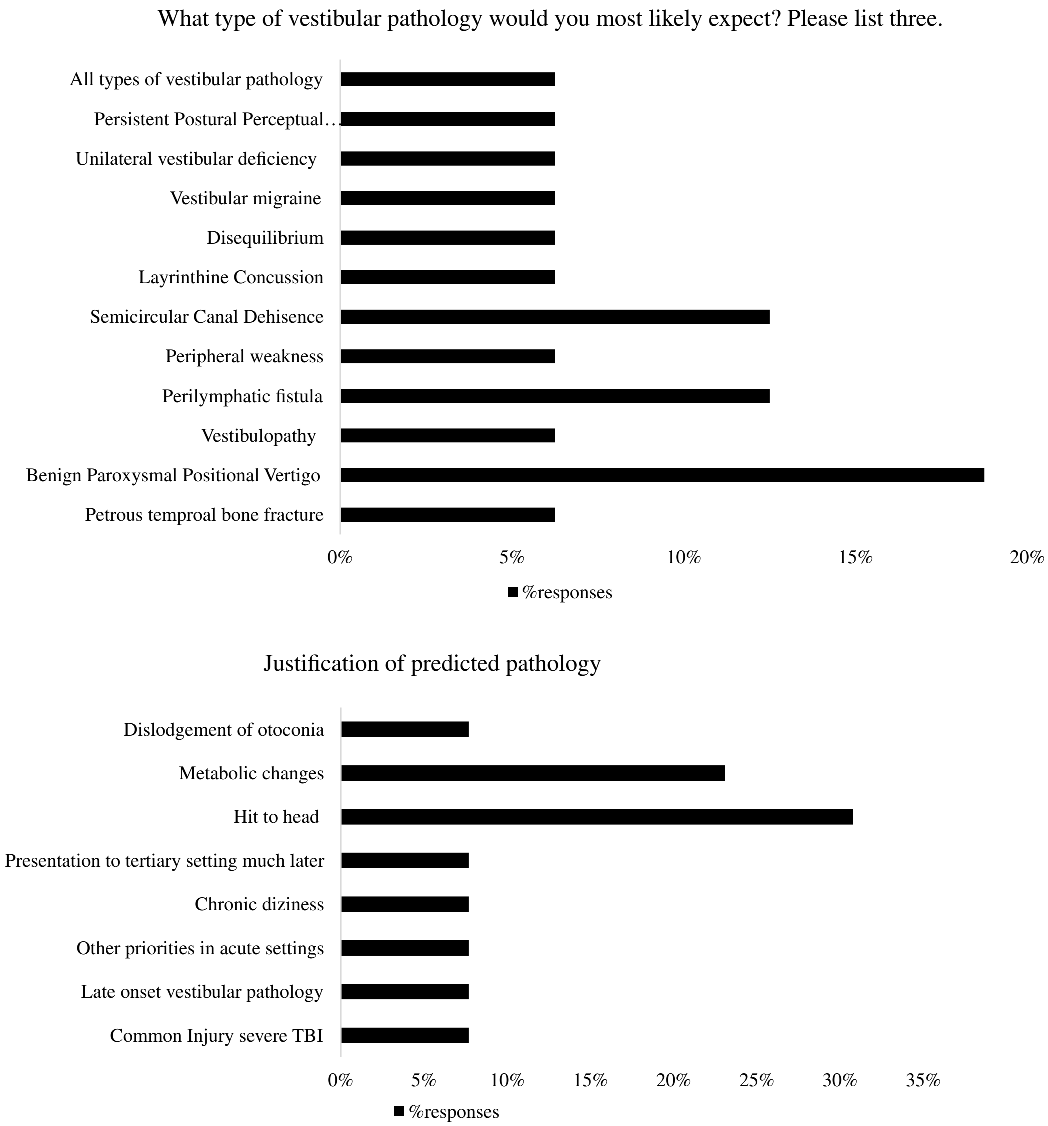

Figure 2. Predicted and justified vestibular pathology following TBI.
Note: These were open-ended questions, the number of responses is reported in text. The most common justification themes relating to the predicted pathology (graph 1) are presented in graph 2.

audiologists reported perilymphatic fistula and two reported semicircular dehiscence, the remainder of participants did not respond to this question. The predicted vestibular pathology was further classified into anatomic regions (i.e., peripheral or central) based on qualitative data, see Fig. 1. The most common themes relating to the audiologists' justification of predicted pathology were, 'hit to the head' reported by four audiologists, followed by 'metabolic changes' by three and dislodgement of otoconia by one audiologist, see Fig. 2.

Table 2 shows the frequency and percentage of audiologists who received training and/or professional development in the diagnosis and management of post-traumatic hearing loss and vestibular dysfunction, indicating most audiologists, 91.1% and 85.7%, respectively, reported not receiving training. Further, content analysis of open-ended questions revealed that of those

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Table 2. Percentage of audiologists who received training or professional development in the diagnosis and management of hearing and vestibular deficits in patients with TBI

Type of loss	Training received Frequency	Training received Percentage (%)	Training not received Frequency	Training not received Percentage (%)
Hearing (n = 43)	3	6.7 %	41	91.1 %
Vestibular (n = 14)	2	14.3 %	12	85.7 %

audiologists who received training, such training involved either in-house training (acute settings), or professional development from the American Academy of Audiology or the American Institute of Balance.

Section C: clinical practice

Exploration of clinical practice in the context of TBI revealed that more than half (55.3%) of audiologists surveyed did not inquire about history of head injury during case history taking, while 44.7% did. In the event of patient confirmation of past head injury, the majority (97.9%) of audiologists reported seeking further clarification. Content analysis of type of information sought revealed the following themes according to frequency of identification by participants: *time of injury* 64%, *nature of injury* 53%, *symptoms* 29% and *management* 24% of respondents. Only 11% of audiologists reported enquiring about loss of consciousness and comorbidities. Seventy-three per cent of audiologists reported seeing a patient with TBI in the past month, with 29.8% altering their diagnostic test battery and 44.7% their rehabilitation plans for patients with TBI. Of those audiologists who reported having seen patients with TBI in the past month, the most common causes of TBI involved *MVA*, 40% of respondents, *falls* by 10% and *sporting accidents* by 10% of respondents, as revealed through content analysis see Table 3.

Forty-six per cent of audiologists reported not altering their diagnostic test battery and 11.1% their rehabilitation plans for patients with TBI, the remainder of respondents reported that such alterations were not applicable at 23.4% and 36%, respectively, see Table 3. Of those 14 audiologists who reported altering their test battery, the most common choice of test reported was *objective tests* by 29% of respondents, followed by *vestibular evaluation* by 21% and *paediatric type assessment* by 14% of respondents. Of those 21 audiologists who reported altering their rehabilitation plans, the most common alteration was *assistance with hearing aid management* reported by 62% of respondents followed by *rehabilitation tailored to patient need* reported by 29% and provision of *easy-to-use hearing aids* reported by 24% of respondents, as revealed through the content analysis.

In the context of vestibular settings, of the 12 vestibular audiologists who responded to section C, nine inquired about head injury during case history taking, while all sought further information following patient confirmation of past head injury, see Table 3. Two vestibular audiologists reported seeing a patient with TBI in the past month. Eight audiologists reported altering their diagnostic test battery, and seven their rehabilitation plans for patients with TBI, see Table 3. Of those eight audiologists who altered their test battery, the choice in tests was varied including the *Dix Hallpike maneuver, Tullio's test, fistula test, objective tests, video Head Impulse test and avoidance of minishaker for VEMP*. Two vestibular audiologists cited the need for clarification from the referring physician and amending the test battery only if the patient was unable to perform the test/s accurately. Further, of those seven vestibular audiologists who reported on altering their rehabilitation plans, 5 reported referring to other professionals, three to a physiotherapist and three to a neurologist.

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Table 3. Auditory and vestibular settings, clinical practice in the context of traumatic brain injury

Clinical Practice in the context of Traumatic Brain Injury (TBI), N = 50	Yes Frequency, [percentage]	No Frequency, [percentage]	Unsure/NA Frequency, [percentage]
Clinical Practice in the context of TBI (Auditory) n = 47			
i. Case History			
Do you inquire about history of head injury?	21 [44.7]	26 [55.3]	
Do you seek further information following patient confirmation of prior head injury?	46 [97.9]	1 [2.1]	
ii. Diagnosis and management of HL following TBI			
In the past month, have you seen patients with hearing loss who have suffered TBI?	10 [21.7]	34 [73.9]	2 [4.3]
Do you alter your diagnostic test battery for patients with TBI?	14 [29.8]	22 [46.8]	**11 [23.4]**
Do you alter your rehabilitation plan for patients with TBI?	21 [44.7]	9 [11.1]	**17 [36.2]**
Clinical Practice in the context of TBI (Vestibular) n = 12			
i. Case History			
Do you inquire about history of head injury?	9 [75]	3 [25]	
Do you seek further information following patient confirmation of prior head injury?	12 [100]	0 [0]	
ii. Diagnosis and management of HL following TBI			
In the past month, have you seen patients with vestibular loss who have suffered TBI?	2 [16.7]	9 [75]	1 [8.3]
Do you alter your diagnostic test battery for patients with TBI?	8 [66.7]	4 [33.3]	
Do you alter your rehabilitation plan for patients with TBI?	7 [58.3]	5 [41.7]	

When asked to report on the three most important things to consider when working with patients with TBI, 21 audiologists [auditory diagnosis and rehabilitation setting] responded, of whom approximately a third (8/22) reported *comorbidities* as an important consideration, followed by *integration of management* reported by seven audiologists and *increased patience in working with the patient* reported by four of audiologists. Of 11 audiologists [vestibular setting] who responded, six reported *manual handling* and *neck/back injury* as the most important considerations, followed by *comorbidities including cognitive impairment* reported by four and *hearing loss* reported by two.

Section D: education and information provision (open-ended questions)

Four open-ended questions were included in Section D to explore the education and information services audiologists offer in both auditory and vestibular settings to patients with TBI and their families. The following questions were asked, *1) What information do you provide patients with TBI regarding their hearing difficulties and strategies? 2) What information do you provide to patients with TBI regarding their balance difficulties and strategies? 3) What education do you provide to families and patients regarding their hearing difficulties and strategies? and 4) What education do you provide to families and patients regarding their balance difficulties and strategies?*

Forty-six of 50 participants, 92%, responded to the first open-ended question, 68% (n = 34) to the second, 90% (n = 45), to the third and 98% (n = 49) to the fourth open-ended question.

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Ninety-six responses were recorded against question one, 41 responses against question two, 90 against question three and 62 against question four.

Analysis of responses to *question one*, revealed that 54% of audiologists would provide patients with post-traumatic hearing loss with the same information they would any other patient with hearing loss. Most responses centred around the information audiologists would generally provide to patients with hearing impairment, including communication strategies, impact of hearing loss, rehabilitation implications and implications of hearing on communication. In the context of TBI, very few audiologists 9% (n = 4) reported simplifying the audiogram and 20% (n = 9) indicated adjusting information depending on the patients' cognitive ability. Referral to other health/medical professionals, and Ear Nose and Throat specialists was reported by a very small proportion of audiologists, 4% (n = 2) and 7% (n = 3), respectively. Only one audiologist reported the provision of counselling and one audiologist a discussion of additional support services for patients with hearing loss in the context of TBI.

Of 34 audiologists who responded to *question two,* 41% (n = 14) were either unsure, did not specify or did not provide any information to patients with post-traumatic balance difficulties. Only two audiologists reported offering information about the implications of balance disturbances and four reported recommending vestibular assessments. Twenty-nine per cent indicated they would recommend a referral to another medical or allied health professional, including physiotherapy, ENT, GP, or multidisciplinary team on concussion.

Of 45 audiologists who responded to *question three*, 51% reported they would educate patients and their families on communication strategies. Education around hearing aid rehabilitation was the second most reported recommendation to patients and their families by 33% of audiologists. Additionally, 9% of audiologists reported involving a significant other in the treatment and management plan, 16% would educate the patient on the impact of hearing loss, 7% of audiologists reported to educate the patients on the importance of patience during their rehabilitation journey. Further, 13% of audiologists reported on providing counselling (i.e., tinnitus, hearing loss acceptance, hearing rehabilitation expectations), 9% would provide the same education as with any other patient and 13% were unsure.

Forty-nine audiologists responded to *question four* in the vestibular settings section of the survey. Of these 49% (n = 24) were unsure of the type of education to provide the patients and their families, and 18% (n = 9) reported they would be able to offer a limited amount of information, as this is outside their scope of practice. Thirty-seven per cent (n = 18) indicated they would recommend a referral to another medical or allied health professional (i.e., physiotherapy, ENT, GP, Neurologist).

Discussion

The primary goal of this study was to describe the typical non-specialist Australian audiological practice in the context of TBI and to determine whether such practices are holistic and incorporate consideration of TBI-related complexities pertaining to diagnosis and management of this patient population. Notably, given that most Australian audiologists practicing in non-specialised audiological settings are unlikely to encounter patients with blast-related injuries and are more likely to encounter patients with non-blast-related TBI, we aimed, as a baseline, to describe the typical practice within the constraints of general Australian audiological practice. The findings revealed clear gaps in knowledge and practice across all survey domains including identification, diagnosis and management of patients with auditory and/or vestibular deficits following TBI. Another important factor that emerged from the findings is one of limited training (i.e., professional development) which is intrinsic to contemporary evidence-based practice in the context of TBI, for maximising the patients' degree of functional capacity (Chua, Ng, Yap, & Bok, 2007; Khan, Baguley, & Cameron, 2003; Lew et al., 2007; Maas et al., 2017). Such gaps in training opportunities are acting as a contextual barrier to the delivery of optimal clinical practice in this patient population. Indeed, several areas of patient care that could benefit from TBI focussed clinical practice training could be identified through consideration of participant responses.

First, over half the surveyed audiologists reported not routinely inquiring about head injury during case history taking. While most audiologists who reported inquiring about head injury sought further information (i.e., time of injury, nature of injury, symptoms and management), very few participants inquired about loss of consciousness and any potential comorbidities. This finding is concerning given the impact past head injuries have on patient outcomes (Maas et al., 2017). In the context of TBI and during case history taking, it is imperative for the audiologist to not only explore the possibility of head injury, including 'hits to the head', but also enquire about loss of consciousness, injury severity, hospitalisation, changes in alertness, speaking or other possible signs of injury (American Speech-Language-Hearing Assocation, n.d.-b; Šarkić, Douglas, & Simpson, 2021a). The use of patient-reported outcome measures (PROMS), including the Hearing Handicap Inventory for Adults (HHIA), Tinnitus Handicap Inventory (THI) and Hyperacusis Questionnaire (HQ) during case history taking will further reveal any functional, social and emotional impacts which are critical in the evaluation of communication abilities. This recommendation of using PROMS in the evaluation of functional ability is supported by Knoll et al. (2020), who reported evidence of considerable disability among patients with post-traumatic auditory symptoms following even mild TBI several years post injury relative to the control group. Further, audiologists must consider the confounding effects of other TBI-related deficits, with some symptoms resolving promptly (Marshall et al., 2015) whilst others persist for a much longer period of time. Symptoms that persist over time including emotional, cognitive and behavioural disturbances pose a significant impact on the diagnosis and rehabilitation of hearing and balance in this patient population (American Speech-Language-Hearing Assocation, n.d.-b; Marshall et al., 2015; Ontario Neurotrauma Foundation, 2018).

Second, although two thirds of the surveyed audiologists reported expecting a patient to present with hearing loss following TBI, the remainder either did not expect a hearing loss or were unsure. Further, contrary to contemporary literature indicating SNHL as the most common post-traumatic hearing deficits (Bramlett & Dietrich, 2015; Emerson, Mathew, Balraj, Job, & Singh, 2011; Knoll et al., 2020; Munjal et al., 2010a, 2010b; Šarkić et al., 2019; Šarkić et al., 2021a), only a tenth of surveyed audiologists reported SNHL as the most likely type of post-traumatic hearing loss. Similarly, one in two surveyed audiologists reported expecting a patient following TBI to present with vestibular pathology, with BPPV reported as the most likely vestibular deficit citing trauma to the head and the resultant dislodgment of otoconia as the cause. While this is an encouraging finding given that head trauma is the most common cause of acquired BPPV, accounting for 15–20% of all BPPV cases (Baloh, Honrubia, & Jacobson, 1987; Hughes & Proctor, 1997; Katsarkas & Kirkham, 1978), it is important to note that half of the surveyed audiologists either did not expect patients with TBI to present with post-traumatic vestibular pathology or were unsure. This finding is particularly problematic given poorer prognostic features associated with traumatic BPPV (t-BPPV) compared to idiopathic BPPV (Roberts, Gans, Kastner, & Lister, 2005), including greater recurrence rates and greater bilateral vestibular system involvement (Gordon, Levite, Joffe, & Gadoth, 2004; Katsarkas, 1999; Liu, 2012; Šarkić, Douglas, & Simpson, 2021b).

Third, while two thirds of the surveyed audiologists reported that diagnosis and rehabilitation of auditory and vestibular pathology in the context of TBI differed to that of a typical audiological patient, nearly half did not routinely alter their typical audiometric diagnostic test battery and a third did not alter their typical vestibular test battery. Failure to alter the diagnostic test battery specific to the patient's case history (i.e., history of TBI) may result in a missed diagnosis of post-traumatic audio-vestibular disturbances, subsequently influencing the rehabilitation outcomes. The low reported rates of altering the diagnostic test battery may partly be explained by the lack of equipment available in the audiologists' place of employment. Although some audiology clinics

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may have been equipped with additional tests, these were not necessarily utilised during the diagnostic process. Further, of those surveyed audiologists who altered their test battery, the most common alteration included the use of objective tests and paediatric tests where the alteration was consistent with assessing a 'difficult to test client' rather than the neuropathology of TBI. Notably, alteration to include objective tests and the Dix Hallpike manoeuvre indicates that these tests do not form the participants' typical test battery.

Given the frequency of peripheral hearing loss (Šarkić et al., 2019), tinnitus (Folmer & Griest, 2003; Kreuzer, Landgrebe, Schecklmann, Staudinger, & Langguth, 2012; Vernon & Press, 1994) and dizziness (Arshad et al., 2017; Davies & Luxon, 1995; Šarkić et al., 2020) following non-blast-related TBI and the associated functional limitations even in mild TBI (Knoll et al., 2020), a specifically tailored TBI audiological assessment is warranted. Alterations to the typical audiological test battery will assist audiologists in implementing adequate rehabilitation plans for patients with post-traumatic audio-vestibular disturbances. Consideration of brain adaptation mechanisms on the auditory and vestibular system neuroplasticity (i.e., neuroplastic changes), influencing symptom progression/recovery over time and/or vestibular compensation, on rehabilitation plans is further warranted.

While the typical audiological test battery in most non-specialised Australian audiology settings (e.g., rehabilitation clinics), includes tympanometry, pure tone audiometry, speech testing and acoustic reflex testing, Audiology Australia recommends clinicians exercise their own judgement when selecting evidence-based tests in providing hearing health care (Audiology Australia, 2013, 2022). The recommended guidelines pertaining to diagnosis and management of post-traumatic audio-vestibular deficits have been published in some countries (e.g., USA) (American Speech-Language-Hearing Assocation, n.d.-b), however, equivalent guidelines in Australia do not exist. To provide Australian audiologists with guidance for clinical practice in the context of TBI, we recently published a summary of recommendations (Šarkić et al., 2021a).

Further, in patients with TBI there is evidence of auditory function disturbances in the absence of measurable hearing loss (Nölle, Todt, Seidl, & Ernst, 2004; White, Duquette-Laplante, Jutras, Bursch, & Koravand, 2022). While these disturbances, recorded through impaired performance on complex speech tasks (e.g., dichotic listening) may be secondary to peripheral auditory, central auditory or cognitive factors (Turgeon, Champoux, Lepore, Leclerc, & Ellemberg, 2011), audiologists need to remain aware that central auditory manifestations may well be present in the absence of auditory threshold elevation in this patient population (Vander Werff, 2016; White et al., 2022).

From a vestibular system evaluation, it is encouraging that of those audiologists who reported altering their diagnostic test battery, Dix Hallpike manoeuvre was the reported test of choice. This is consistent with current recommendations based on the significant prevalence of BPPV in patients with TBI (Ahn et al., 2011; American Speech-Language-Hearing Assocation, n.d.-b; Bhattacharyya et al., 2017; Marshall et al., 2015; Šarkić et al., 2021b). While a universally accepted protocol for traumatic BPPV diagnosis and management does not exist, audiologists should consider the heightened likelihood of bilateral BPPV, multi-canal involvement and the possibility of initial treatment failure in traumatic BPPV (Ahn et al., 2011; Marshall et al., 2015). For a more detailed account summarising recommendations for audiologists working patients with post-traumatic BPPV, see our recent publication (Šarkić et al., 2021b).

Moreover, the implementation of adequate and successful rehabilitation plans for patients with post-traumatic auditory and/or vestibular disturbances relies on a thorough case history taking and diagnosis through relevant assessment procedures, as indicated above. While most surveyed audiologists in auditory diagnostic/rehabilitation settings reported altering their rehabilitation plans for patients with TBI, the cited modifications (i.e., device management, provision of user-friendly devices) are somewhat simplified and lacking a specifically tailored TBI approach. Research exploring specific diagnosis and management of post-traumatic auditory and vestibular disturbances is scarce and specific best practice guidelines do not exist, however, the Ontario

Neurotrauma Foundation (2018) and American Speech-Language-Hearing Assocation (n.d.-b) address the role of audiologists within the audiological scope of practice for diagnosis and management of patients with TBI.

During the rehabilitation process, audiologists must consider that complexities associated with TBI are multifactorial, including comorbidities such as cognitive fatigue, changes in personality and behavioural patterns, concentration difficulties, memory problems and sensory changes (i.e., vision, smell, hearing and balance). Given that cognitive symptoms and the associated maladaptive responses have the potential to interfere with treatments for the above comorbid conditions, patients with TBI may not be able to independently follow through treatment recommendations (American Speech-Language-Hearing Assocation, 2017), affecting the overall audiological diagnosis and management (American Speech-Language-Hearing Assocation, n.d.-b; Marshall et al., 2015; Ontario Neurotrauma Foundation, 2018; Šarkić et al., 2021a). Therefore, during the rehabilitation process, audiologists are strongly encouraged to not only modify plans in accordance with the patient's specific injury presentation but also review hearing and communication needs more frequently given the largely unknown progression of post-traumatic auditory deficits.

Most importantly, the overall goal of intervention for patients with TBI is to assist the person to maximise independent function post injury consistent with the principles of the International Classification of Functioning (ICF), (World Health Organization, 2001). Although historically, the profession of audiology has centred on the biomedical model of care (i.e., emphasis on technical skills), a shift towards the biopsychosocial model of care that considers the person's physical, social, emotional and motivational factors is strongly recommended. While a mismatch between audiological service delivery and the ICF principles exists (Tai, Barr, & Woodward-Kron, 2018, 2019), in the context of TBI rehabilitation, several stakeholders (i.e., researchers, practitioners, policy makers) consider the provision of holistic biopsychosocial care as the leading approach for brain injury rehabilitation (Kontos et al., 2012; Williams & Evans, 2003; Wright, Zeeman, & Biezaitis, 2016).

In terms of information provision for patients and their families relating to post-traumatic hearing and balance deficits, the surveyed audiologists reported providing the same information they would provide to any other patient (i.e., communication strategies, impact of hearing loss) but were unsure of the type of information they would provide a patient with post-traumatic balance deficits. While provision of communication strategies and information on the impact of hearing loss are important aspects of audiological service delivery, for patients with TBI *a person-centred focus on function* (American Speech-Language-Hearing Assocation, n.d.-a) is required. More specifically, rehabilitation following TBI is nearly always a long-term process and therefore necessitates a multidisciplinary, holistic and tailored patient rehabilitation plan (Ptyushkin, Vidmar, Burger, & Marincek, 2010). While the following recommendations are not audiology-specific, they provide opportunities for health practitioners, including audiologists, to maximise their holistic practice whilst focusing on assessment processes and building relationships (Wright et al., 2016). These include, a) building and maintaining rapport with patients and their families, b) engaging patients and their families in the rehabilitation process (i.e., goals and recovery) utilising the biopsychosocial model of care, c) ensuring the comprehensive assessment process includes a mutual understanding across all relevant parties (i.e., audiologist, patient and their family) and ensuring the assessment process is conducted in a collaborative manner and d) ensuring detailed information is provided to the patient, their family and other team members involved in the rehabilitation journey. It is imperative that communication lines remain open across the rehabilitation trajectory (Wright et al., 2016). Until audiology-specific guidelines for information provision and rehabilitation are developed, the above recommendations offer a starting point.

Finally, given the complexity of TBI sequelae, a comprehensive multidisciplinary approach specifically tailored to TBI rehabilitation is fundamental to improved patient outcomes (Bayley et al., 2014; Maas et al., 2017). Hearing and balance disorders should be routinely investigated, and the discipline of audiology integrated into the multidisciplinary team in the rehabilitative journey of the patient and their family.

Limitations

Caution should be exercised in generalising the present results due to several limitations. First, the *small sample size* of this survey needs to be acknowledged. Clearly a substantially higher response rate would be necessary for the purpose of establishing a representative baseline of national audiological practices in the context of TBI. Second, *response bias* associated with self-selection of participants and of self-reported data can prove to be problematic with respect to validity, reliability and generalisability of findings across the profession (Rosenman, Tennekoon, & Hill, 2011). Third, given that Audiology Australia relies on clinicians to exercise their own judgement in determining the provision of patient care based on individual patient needs, potential inconsistencies between clinics are possible. Despite the typical audiological test battery consisting of a series tests outlined earlier in this paper, this survey would have benefited from a detailed participants' account of the specific clinical protocols utilised in their clinical settings. Thus, this study is best considered not only exploratory in nature but also a preliminary description of the typical Australian non-specialist audiological practice in the context of TBI and the findings indicative of audiological service provision within these confines. Finally, this preliminary study was based on audiologists' reports of their current clinical practice, but the reasons behind their choices and any potential barriers hindering optimal practice were not investigated. Understanding the rationale behind individual choices would assist in identifying the factors that were potentially hindering optimal service delivery in this patient population. Therefore, a follow up to this investigation involving an in-depth qualitative inquiry exploring audiologists' perspectives of barriers and associated solutions in the context of TBI-related audiological service delivery was conducted and recently published (Douglas and Simpson, 2022).

Conclusion

The current study investigated the typical non-specialist Australian audiological practice in the context of TBI and whether such practices incorporate consideration of TBI-related complexities to maximise rehabilitation outcomes. While the focus of this preliminary investigation centred on non-blast-related TBI and the resultant peripheral audio-vestibular disturbances, future research investigating Australian audiological practice in blast-related injury and central system involvement is warranted. Within the confines of the current investigation, knowledge gaps were evident across all survey domains, including *training, clinical practice* and *information provision to patients and their families,* pertaining to identification, diagnosis and management of patients with auditory and/or vestibular deficits following TBI. A lack of understanding of the implications of co-morbidity and multimorbidity on post-traumatic hearing and balance diagnosis and management was evident. It is likely that a lack of resources, equipment availability and audiological training in the context of TBI have influenced current practice. An in-depth qualitative inquiry investigating audiologists' perceived barriers relating to audiological practice in the context of TBI is underway. The identification of these gaps may encourage audiologists to modify their practice and provide a more tailored approach to their patients with TBI.

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