Mobile Health School Screening and Telemedicine Referral to Improve Access to Specialty Care in Rural Alaska: Integrating Mixed Methods Data to Contextualize Trial Outcomes

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Objectives: To understand factors associated with outcomes in a cluster-randomized controlled trial that evaluated a telemedicine specialty referral intervention for school hearing screenings in 15 rural Alaskan communities.

Design: Hearing Norton Sound was a mixed methods cluster-randomized controlled trial that compared a telemedicine specialty referral pathway (intervention) to a standard primary care referral pathway (control) for school hearing screenings. As a mixed methods trial, both quantitative and qualitative data were collected, analyzed, and integrated. Main trial results are published elsewhere, but integration of community-specific quantitative outcomes and qualitative results have not yet been reported. The constant comparative method was used to analyze qualitative data from semistructured interviews with six stakeholder groups across all 15 communities. Descriptive statistics were used to describe community-specific proportions of follow-up in both trial years. Qualitative and quantitative results were integrated to reveal relationships between contextual factors and follow-up outcomes across communities.

Results: The Hearing Norton Sound trial enrolled 1481 children from October 2017 to March 2019, with a total of 790 children requiring referral. Of the children who referred in the telemedicine specialty referral pathway communities (intervention), 68.5% received follow-up (268/391), compared to 32.1% (128/399) in primary care referral communities (control)(previously reported). When broken down by community, the mean proportion receiving follow-up was 75.26% (SD 22.5) and 37.9% (SD 11.4) for the telemedicine specialty referral communities and primary care referral communities, respectively. For qualitative data collection, semistructured interviews were conducted with 101 individuals between December 2018 and August 2019. Six stakeholder groups participated: elders (n = 14), parents (n = 25), children (n = 11), teachers/school staff (n = 18), principals (n = 6), and healthcare providers/clinic staff (n = 27). Six overall factors related to the outcomes of the telemedicine specialty referral pathway emerged during analysis*: clinic capacity, personnel ownership and engagement, scheduling, telemedicine equipment/processes, communication*, and *awareness of the need for follow-up*. We integrated these factors with the community-specific follow-up percentages and found associations for four of the six qualitative factors: *clinic capacity, personnel ownership and engagement, communication,* and *awareness*. An association was not seen for *scheduling* and *telemedicine equipment/processes*, which had variable relationships with the follow-up outcome.

Conclusions: The Hearing Norton Sound trial demonstrated that a telemedicine specialty referral pathway can close the gap on children lost to follow up after school hearing screening. As a whole, the intervention profoundly increased the proportion of children receiving follow-up, but there was variability in outcomes within and between communities. To understand this variability, we analyzed community-specific intervention outcomes alongside community member feedback on factors related to the intervention. We identified four key factors that contributed to the success of the intervention. Attention to these factors will be essential to successful adaptation and implementation of this telemedicine specialty referral intervention and other similar interventions in future work in rural Alaska and beyond.

Key words: Community-based hearing research, Hearing Norton Sound, Joint display, Mixed methods integration, Qualitative methods, Rural Alaska.

Abbreviations: BSSD = Bering Strait School District; CHA/P(s) = Community Health Aides/Practitioner(s); CTS(s) = Clinic Travel Specialist(s); NSHC = Norton Sound Health Corporation.

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IDEA

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INTRODUCTION

School hearing screening is widely recognized as an essential measure for identification, prevention, and treatment of childhood hearing loss (Wilson et al. 2017; Yong et al. 2020). However, loss to follow up is a ubiquitous issue in school-based screenings programs of all types, including hearing screening

(Allen et al. 2004; Kimel 2006; Wang et al. 2011; Skarzynski et al. 2016; Rodriguez et al. 2018). Annual school hearing screening is mandated in Alaska, but without robust follow-up pathways, screening programs can be rendered ineffective. This is particularly concerning in rural and Indigenous Arctic communities, which can experience a disproportionately high prevalence of childhood infection-related hearing loss (Reed et al. 1967; Singleton et al. 2009). These rural communities also face overlapping challenges in health outcomes due to the impact of structural racism (Burns et al. 2021; Solomon et al. 2022) and geographical distance from specialty providers. Telemedicine presents an opportunity to improve health outcomes, including access to ear and hearing care. Previous studies have shown that telemedicine for ear and hearing care reduces patient wait times and results in medical decision-making comparable to an in-person examination (Patricoski et al. 2003; Kokesh et al. 2008, 2009). However, Alaska's robust telemedicine infrastructure has never before been systematically utilized for preventive care, such as school hearing screenings.

Hearing Norton Sound was a cluster-randomized controlled trial that compared a telemedicine specialty referral pathway (intervention) to the standard primary care referral pathway (control) following school hearing screenings (Emmett et al. 2019a). The trial enrolled students (K-12th grade) over two academic school years, from October 2017 to March 2019, in 15 communities in the Bering Strait region of Northwest Alaska. Hearing Norton Sound was designed as a mixed methods trial, with the goal of collecting, analyzing, and integrating both quantitative and qualitative data (Emmett et al. 2019b). Integration is the combination of quantitative and qualitative methods so that associations and conclusions can be drawn using the richness of both data sets (Fetters et al. 2013; Guetterman et al. 2015).

Quantitative results from the trial, reported elsewhere, showed that children in telemedicine referral communities were 2.3 times more likely to receive follow-up than those in primary care referral communities, and follow-up occurred 17 times faster (Emmett et al. 2022). Factors that contributed to the success of the telemedicine intervention had not yet been evaluated, however. To answer this question, we examined the proportion of children who received follow-up within each of the 15 communities to look for community-specific follow-up patterns. We also conducted a qualitative analysis of stakeholder semi-structured interviews to assess factors related to the telemedicine intervention and ear and hearing care in general. We then aligned the community-specific quantitative and qualitative results to identify potential patterns that could have contributed to follow up outcomes. Our goal was to identify key factors that contributed to follow up outcomes and potential areas for refinement of the telemedicine intervention.

MATERIALS AND METHODS

Overview

Hearing Norton Sound was a cluster-randomized controlled trial conducted in schools in 15 communities in the Bering Strait region of Northwest Alaska (Fig. 1) (Emmett et al. 2019a). Community engagement and involvement were central to the design of the trial and have been described elsewhere (Robler et al. 2020). The mixed methods trial combined both quantitative and qualitative methods, and details regarding trial design, methodology, and primary results have been previously published (Emmett et al. 2019a,b, 2022). The trial was approved by the Alaska Area Institutional Review Board, Duke University Institutional Review Board, and Norton Sound Health Corporation Research Ethics Review Board.

The Bering Strait region is served by the Bering Strait School District (BSSD), which operates a K-12 school in each of the region's 15 communities. The healthcare organization in the region is Norton Sound Health Corporation (NSHC), a nonprofit tribal health organization which operates a clinic in each of the region's 15 rural communities, including a subregional clinic in Unalakleet, in addition to a regional hospital in Nome, the region's hub town. Community clinics are staffed primarily by Community Health Aides/Practitioners (CHA/Ps), who live in and provide frontline health care to the region's rural communities ("Overview of the Alaska Community Health Aide Program," 2005). Clinics are also staffed by Clinic Travel Specialists (CTSs), administrative staff who coordinate patient travel and schedule clinic appointments. Some clinics also staff Advanced Practice Providers (e.g., nurse practitioners and physician's assistants). The regional hospital in Nome and the subregional clinic in Unalakleet staff onsite audiologists with a full range of services. Audiologists also travel monthly to provide services at each of the local community clinics (known as "field clinics").

Quantitative Methods

Recruitment, screening, and referral processes for the quantitative outcomes have been described in detail elsewhere (Emmett et al. 2022). In short, parents of all children enrolled in BSSD received an informational packet about the trial during the school intake process. All children (grades K-12, ages 4–21) enrolled in BSSD were eligible if parental informed consent and verbal child assent were obtained. Screenings were conducted by study staff and school staff at the community schools. Screenings identified children who had potential ear or hearing concerns, and these children were added to a referral list. The study team transferred the referral list to school leadership, who coordinated the referral pathway depending on their community's randomized assignment to the intervention (telemedicine specialty referral pathway) or control (standard primary care referral pathway). In control communities, schools sent a letter home to families of children that referred screening, recommending they bring their child to the local clinic for follow-up. In intervention communities, schools and clinics coordinated to arrange follow-up appointments for children on the referral list. These appointments were conducted at the community clinics by a CHA/P. Using the well-established store-and-forward or asynchronous telemedicine process in Alaska (University of Alaska Statewide Health Programs 2004), trained CHA/P collected additional information, such as otoscopy, tympanometry, and otoacoustic emission and/or automated pure tone testing, on the child's ears and hearing and sent the information as a telemedicine case to an NSHC audiologist for asynchronous review. The audiologist reviewed the case and sent clinical recommendations back to the CHA/Ps, who then communicated these recommendations to the parent, guardian, and/or child as appropriate. If medical or surgical management was indicated, the telemedicine case was sent to an otolaryngologist to review at the state tertiary hospital in Anchorage, Alaska. Examples of treatment from the telemedicine case included immediate medical management (e.g., antibiotics or drops for active infections), recommendations for surgery, continued monitoring via

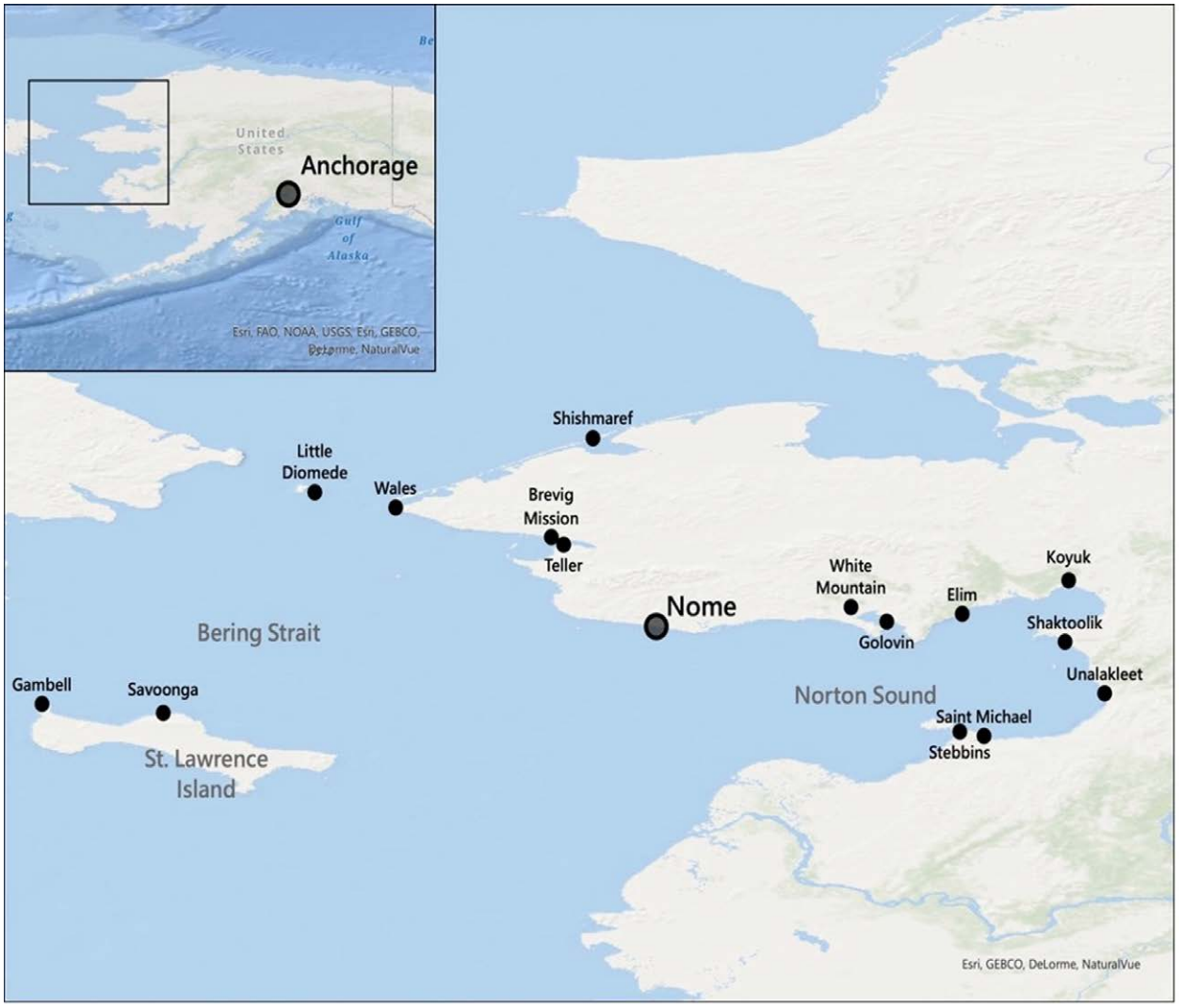

Fig. 1. Map of communities in Bering Strait region in Northwest Alaska.

telemedicine, or scheduling of in-person appointments for additional testing or a hearing aid evaluation either at the regional hospital in Nome or during village field clinics to the community. A review of the medical record was completed for all children enrolled in the study who referred screening to determine if they received follow-up within 9 months of their screening date. The study team then computed the proportion of children who received follow-up within each community.

Qualitative Methods

Semistructured interviews were conducted to understand contextual factors associated with the follow-up outcomes (consistent with an explanatory sequential mixed methods design, as described in Emmett et al. 2019b). Six stakeholder groups were included: parents, children, elders, teachers/school staff, principals/school administrators, and healthcare providers/clinic staff. Stakeholder-specific semistructured interview guides were co-developed by the scientific and Alaska Stakeholder Teams (see Robler et al. 2020 for detailed descriptions). Interview guides were tailored for each stakeholder group and included questions about experiences of hearing loss, school hearing screenings, and screening referrals (see Supplemental Digital Content 1, http://links.lww.com/EANDH/B174 for an outline of the interview guides).

A target sample size of 100 participants was set before the start of the trial, with consideration of the need to reach saturation with data from each of the six stakeholder groups across 15 communities (Emmett et al. 2019b). Interviewees were recruited using purposive sampling to maximize heterogeneity of experiences. We sampled for those with experience with ear and hearing care and focused on intervention communities, given the novelty of the telemedicine specialty referral pathway and the aim to capture a breadth of experiences with the new process. We also sampled individuals from intervention communities known anecdotally to have had successes or challenges with the intervention in year 1 of the trial. Recruitment occurred via flyers, local radio, social media, and word of mouth, as well as direct outreach to individuals known to have relevant experiences with hearing-related health care.

Recruitment and data collection occurred during in-person trips to the 15 communities for trial data collection, as well as over phone or video call for individuals who were not reached during in-person trips. All interviews were conducted by trained

study staff, including an individual from the region fluent in St. Lawrence Island Yupik. Interviews were conducted in English except for two, which were conducted in St. Lawrence Island Yupik. Interviews lasted between 30 and 60 minutes each. All participants signed a written informed consent prior to participation. Any participant under age 18 required a signed parent or guardian consent and verbal child assent. Interviews were audio-recorded unless a participant preferred not to be recorded, in which case handwritten notes were taken. Real time notes and debriefing questions immediately following interviews ensured standardization and consistency with both audio and handwritten notes. Select interviews were completed in pairs based on the preferences of the participant(s) (e.g., a mother and child interviewed at the same time).

Data Analysis

Quantitative Data Analysis • Quantitative analyses to determine the overall proportion of referred children seen for follow-up within 9 months of referral by treatment arm has been previously published and analysis described in detail elsewhere (Emmett et al. 2022). To determine proportion of follow-up at the community level for year 1 and year 2 of the trial, community-specific proportions were computed for each year and summarized with descriptive statistics. Mean percentages were stratified by trial year and treatment arm to look more closely at patterns of follow-up.

Qualitative Data Analysis • All audio-recorded interviews were transcribed and de-identified by study staff, and all interviewer notes from non-audio-recorded interviews were typed up and de-identified. All interview data were included in analysis. A preliminary codebook was drafted based on a previous codebook used to analyze the trial's focus group data (Emmett et al. 2019b; Inglis-Jenson et al. 2023). Deductive themes were generated using this codebook and sections from the semistructured interview guides. The study team then used the constant comparative method to refine themes by moving iteratively between data and codes (Glaser 1965; Glaser & Strauss 1967; Boeije 2002). To start, four study team members reviewed selected transcripts from each stakeholder group and suggested edits to the preliminary codebook. Through iterative meetings, these suggestions were discussed and refined into a draft codebook with definitions and inclusion/exclusion criteria. Two study team members then used this draft codebook to independently code the same 10% of the sample. The coders ran coding comparisons and then met to discuss discrepancies and refine definitions to create the final codebook (see Table in Supplemental Digital Content 2, http://links.lww.com/EANDH/B175, for qualitative codebook). Senior study team members and two individuals from the region who served as Alaska stakeholders oversaw this iterative process and approved the final codebook. Then the same two study team members used the final codebook to independently code the remaining 90% of the sample. QSR International NVivo 12 was used for all analyses. After the completion of analysis, the study team presented results, quotes, and themes to community members at interactive community events, to check for relatability of qualitative findings.

Quantitative and Qualitative Integration • To more specifically analyze the factors that contributed to the success of the intervention, two study team members reviewed content coded as "Barriers and Facilitators of Hearing Screening and Referral Process" (see Table in Supplemental Digital Content 2, http://links.lww.com/EANDH/B175, for qualitative codebook). These study team members met iteratively with the Alaska stakeholders to identify subcodes: neutral factors that could manifest as barriers or facilitators to follow-up in all 15 communities. Study team members then merged quantitative and qualitative data from intervention communities to create an integrated data set consisting of quotes organized into factors and labeled with community code, interviewee stakeholder group, and follow-up by year. The team analyzed this data set to see if associations emerged between factors and follow-up proportions and created a joint display, or a visual figure that reports integrated quantitative and qualitative results (Guetterman et al. 2015). As is common in joint displays, the study team grouped quantitative outcomes into "low," "moderate," or "high" categories (Guetterman et al. 2015). To do this, year 1 and year 2 follow-up percentages were first averaged, and then each community's average was sorted from low to high, with 0% to 54.9% considered low, 55% to 84.9% moderate, and 85% to 100% high follow-up. Qualitative data in the joint display are selected representative quotes from analysis, chosen through iterative document review and meetings by the study team (including 2 senior staff) and the Alaska stakeholders.

RESULTS

Quantitative Results: Follow-up Proportions • The Hearing Norton Sound trial enrolled 1481 children (grades K-12, ages 4–21) in the trial from October 2017 to March 2019, with a total of 790 children requiring referral. Of referred children in communities assigned to the telemedicine specialty referral pathway, 68.5% received follow-up (268/391) compared to 32.1% (128/399) in primary care referral communities (previously reported) (Emmett et al. 2022). When broken down by community, the mean proportion that received follow-up was 75.26% (SD 22.5) in the telemedicine specialty referral communities and 37.9% (SD 11.4) for primary care referral communities. **Table 1** provides a breakdown of follow-up percentages by community.

Qualitative Results: Factors Associated With the Telemedicine Intervention • Semistructured interviews were conducted with 101 individuals from all 15 communities between December 2018 and August 2019. Six stakeholder groups participated: elders (n = 14), parents (n = 25), children (n = 11), teachers/school staff (n = 18), principals (n = 6), and health care providers/clinic staff (n = 27). See **Table 2** for basic demographics of stakeholder participants. Six themes emerged as factors that were related to the outcomes of the telemedicine specialty referral pathway: *clinic capacity, personnel ownership and engagement, scheduling, telemedicine equipment/processes, communication,* and *awareness of the need for follow-up*.

Integration of Qualitative and Quantitative Results • Upon merging quantitative and qualitative data from intervention communities (i.e., community-specific follow-up proportions and community-specific quotes), associations emerged between follow-up proportions and four of the six factors: *clinic capacity, personnel ownership and engagement, communication,* and *awareness of the need for follow-up.* In these four factors, patterns emerged where the factor was reported as a facilitator in high follow-up communities, a barrier in low follow-up

TABLE 1. Percent of children who referred a school hearing screening and received ear and hearing follow-up, organized by community, intervention arm, and study year

Community Code	Intervention Arm	Year 1 Follow-up (Mean), %	Year 2 Follow-up (Mean), %
A	Intervention	100.0	100.0
B	Intervention	88.1	100.0
C	Intervention	81.3	95.2
D	Intervention	79.3	82.7
E	Intervention	75.0	72.7
F	Intervention	100.0	40.0
G	Intervention	46.2	56.0
H	Intervention	38.3	49.3
I	Control	40.0	55.6
J	Control	42.0	51.5
K	Control	35.6	46.6
L	Control	27.3	51.6
M	Control	30.0	40.0
N	Control	28.6	41.1
O	Control	22.2	18.2

TABLE 2. Summary of participant characteristics for semistructured interviews

Participant Characteristics		Intervention Communities (N = 68)	Control Communities (N = 33)	Total (N = 101)
Stakeholder group	Elders	3	11	14
	Parents	18	7	25
	Children	9	2	11
	Teachers/school staff	13	5	18
	Principals	4	2	6
	Healthcare providers/clinic staff	21	6	27
Age (years)	5–18	9	2	11
	19–40	29	6	35
	41–55	19	11	30
	56+	11	14	25
Gender	Female	50	21	71
	Male	18	12	30

communities, and a combination in moderate follow-up communities (**Table 3**; bold font quotes are facilitators, regular font quotes are barriers). This pattern was not seen for the other two factors, *scheduling* and *telemedicine equipment/processes.*

Clinic Capacity

In communities with high follow-up, Community Health Aides/Practitioners (CHA/Ps) and Clinic Travel Specialists (CTSs) reported adequate staffing and manageable patient loads at their clinics. These participants also described clear communication amidst clinic staff, an understanding of each other's roles, a clear division of task loads, and a norm of task sharing during busy times at the clinic (see quote 1 in **Table 3**). In communities with low follow-up, CHA/Ps described clinic staffing as a critical limitation, with inadequate staffing often compounded by seasonal illnesses that filled the clinic schedule and precluded preventive care appointments. A CHA/P in a community with moderate follow-up explained that CHA/Ps do believe hearing screening follow-up is important, but when the clinic is under-staffed, they have to prioritize acute and emergent care rather than hearing screening referrals.

Personnel Ownership and Engagement

Interviewees emphasized the impact of staff tenure at the school or clinic, staff investment in the health of their community's children, and staff ownership of processes. A CHA/P in a community with high follow-up explained that staff at both the school and clinic know that they must work together to address children's health. In another community with high follow-up, the CHA/P completing the appointments talked about enjoying the process and found the differences between children's ears interesting (see quote 4 in **Table 3**). Meanwhile, a lack of ownership of the process was described by participants in several communities with low-to-moderate follow-up. A school principal drew boundaries around the school's responsibility to ensure follow-up after screening (see quote 6 in **Table 3**). A special education teacher in a community with a decline in follow-up between year 1 and year 2 stated that the telemedicine specialty referral pathway would need to be one staff person's responsibility in order to be successful (see quote 5 in **Table 3**). A CHA/P in a community with low follow-up said the completion of the telemedicine specialty referral appointments depends on "who's willing to get this done," and described confusion as to whose job it was to complete the follow-up, particularly with audiologists traveling to the community for field clinic. Overall, a school district administrator spoke about the difficulty of building buy-in and knowledge of the process at schools given the high teacher turnover.

Scheduling

Interviewees in communities with high follow-up spoke positively of the clinic driving the scheduling process in the

TABLE 3. A joint display of quantitative and select qualitative data from intervention communities in the Hearing Norton Sound cluster-randomized trial (2017–2020)

Community Code	A	B	C	D	E	F	G	H
Categorical follow-up	High follow-up			Moderate follow-up			Low follow-up	
Year 1 (percent that received follow-up), %	100.0	88.1	81.3	79.3	75.0	100.0	46.2	38.3
Year 2 (percent that received follow-up), %	100.0	100.0	95.2	82.7	72.7	40.0	56.0	49.3
Factors								
Clinic Staffing, Capacity, and Coordination	**1 "…we kind of worked out a flow—somebody handles walk-ins, somebody's seeing regular patients, and somebody could see the telemeds. We always—once we got lists, we always communicate with each other and you know, make it work." [Community Health Aide/Practitioner, Community A]**			**2** "Right now, the clinic has been short staffed. It's been short staffed for years. We've been trying to hire health aides and get them hired and learned up but then they move on we're short staffed again..." [Community Health Aide/Practitioner, Community E]			**3** "We just need more staff, if we had more staff, then it would be a lot easier. Like in my other villages that are better staffed, those kids are current on their Well Child, immunizations—all that kind of stuff, because they have less volume and more people to help them. Versus the higher volume here, and less people…" [Advanced Practice Provider, Community H]	
Personnel Ownership and Engagement	**4 "I really enjoy [the follow-up appointments], actually... kept me busy… just going through one after the other. Just seeing the difference in each kid—it was neat to see all kinds of—the difference between person to person." [Community Health Aide/Practitioner, Community B]**			**5** "...if it's not any one person's responsibility, I don't see it happening, you know? Because if someone thinks 'oh, maybe the school's taking care of it, oh, maybe the clinic's taking care of it, oh, maybe the Special Education teacher's taking care of it.' And if nobody knows and nobody's really assigned, then it's not getting taken care of." [Teacher, Community F]			**6**"—the school's willing to try, but the school's not willing to take the ultimate responsibility for ensuring that every kid that needs hearing services got hearing services… I don't think that's our job… Are we responsible for getting these kids in and getting the permission slips signed for Norton Sound? I would say that that's a no. We are the helpers, assisters, supporters, nurturers, and all that kind of stuff—I think the school could take that role on." [Principal, Community H]	
Scheduling	**7 "The main part was the CTS keeping my schedule open, and making sure the kids get here. And were ready to come back as soon as they see another one leave...she didn't necessarily block it, but we discussed ahead of time that I'm not gonna be seeing patients from this time to this time. Until I get all the [referred screening] kids done." [Community Health Aide/Practitioner, Community B]** **8** The trickiest part was just trying to find a time that worked for everybody. That was the hardest. [Community Health Aide/Practitioner, Community C]			**9 The clinic initiating the conversation [about scheduling a follow-up appointment] could help parents—it'd be coming from a clinical source that's perceived as more of an authority on medical matters. [paraphrased from non- audio recorded interview, Teacher, Community D]**			**10** "…sometimes they wouldn't bring them in, like you'd call them and tell them you need to come in for this, some people just never showed up...there are some people that will bring their kids in just if you say they need to come in, they'll bring their kid in. They'll be like okay. Some won't. Some are probably just too busy and the time doesn't work for them— I don't know." [Community Health Aide/Practitioner, Community H]	
Telemedicine Equipment / Processes	**11** "A lot of times [with specialty care telemedicine cases] parents think that they're only being seen by us [CHA/Ps]…and they want to be seen by someone who has experience for the problem, like if they're being seen for the ear or for the eyes, they want to be seen by a person that knows." [Community Health Aide/Practitioner, Community B]			**12** "Sometimes like when the case is sent to Audiology and then sent to ENT, especially on Fridays, you don't get a response back until Monday or Tuesday…I think patience is the biggest…like their waiting time….it's the biggest complication doing the telemed cases." [Community Health Aide/Practitioner, Community F]			**13 "I think the sooner we know about an issue and the sooner it's treated, the better it is. Anytime you can expedite something [via telemedicine] it's definitely better." [Community Health Aide/Practitioner, Community H]**	

(Continues)

TABLE 3. (*Continued*)

Community Code	A	B	C	D	E	F	G	H
Communication	**14 "Communication is the key. Um, and then the health aide coming up with a plan of like which part of the classes they're ready for. Because we have a group of kids coming in throughout the day, and so—coordinating with the school—the relationship is very, very good." [Clinic Travel Specialist, Community A]** **15 "It's very understanding, you know, everybody—we communicate, understand each other. And we're coming from—that we're helping the kid. So we just acknowledge that we're caring for your kid and this is, you know, to help them because it'll effect their learning."[Community Health Aide/Practitioner, Community A]**			**16** "I would just like to say that I've gotten like no information back about students from the clinic, ever. I've never received anything, and it's not even just for Audiology, I've never heard … what they're doing or you know, ways I can assist. I've not had any communication from the clinic specifically…" [Teacher, Community D] **17** You know; I think [the school] gets along really well with our clinic…I think we're fortunate..." [Teacher, Community E]			**18** "Some people, like myself, I got a monthly plan— month to month, sometimes I don't have enough money to pay my bill for a while. So sometimes I go a few days without a phone. So sometimes a phone [call] won't work…" [Parent, Community H] **19** Communication is not there. It used to be…the previous secretary would send home a lot of information on paper. Knowledge is so much, it's everything…there was always good communication between the school and the clinic with the previous secretary. [paraphrased from non-audio recorded interview, Clinic Travel Specialist, Community G]	
Awareness	**20 "The parents are really willing to get it done. And know the important parts of it. So once they know to come in, they come in right away with their kiddo." [Community Health Aide/Practitioner, Community A]**			**21** "Maybe the kid might be ashamed of having a hearing problem. I think my friend is ashamed of having a hearing problem and I think she was ashamed to use her hearing aids because she's young but I tried to tell her she could just use them cause I don't think anyone would judge her…."[Child, Community F]			**22 "I think it's awesome I can see my daughter's ear drum right on the screen in front of me and say wow, that— that looks horrible you know, let's try to fix this…" [Parent, Community H]** **23** You can tell the parents to come, but if they don't want to, they won't bring them in.…the school and the secretary could be doing their job, but the parent isn't going to bring them because they're not sick. It's education! Tell the parents why they're getting referred, what's going on, if they child is not taken care of what it could lead to. [paraphrased from no-audio interview, Clinic Travel Specialist, Community G]	
Integration Summary	Participants in communities with high follow-up described ample *clinic capacity*, engaged *personnel*, consistent and clear *communication*, and *awareness* of the need for follow-up as contributing to the success of the intervention. Challenges were described for *telemedicine equipment/processes,* and *scheduling* was described as both a barrier and a facilitator.			Participants in communities with moderate follow-up described factors as both facilitators and barriers. Variation in quantitative follow-up was seen even between years, as in Community F, where qualitative data revealed that a lack of *personnel ownership*, the time intensiveness of *telemedicine processes*, and stigma (*awareness*) may have contributed to decreased follow-up in year 2.			Participants in communities with low follow-up described a lack of *staffing capacity*, unclear *ownership of the process*, *communication* barriers, and lack of education (*awareness*) about referrals as barriers to the intervention. *Telemedicine processes* were described positively, exemplifying how feedback on *telemedicine processes* wasn't consistently associated with follow-up percentages.	

Community-specific follow-up percentages are presented as an average over the two study years and sorted categorically (0%–54.9% low, 55%–84.9% moderate, and 85%–100% high follow-up). Key representative quotes from analysis are listed within each community and factor. Bold text indicates that the quote describes a factor as a facilitator of the telemedicine intervention. Quote numbers are referenced throughout the article.

telemedicine specialty referral pathway, as opposed to the parents scheduling follow-up in the standard primary care referral pathway. A CHA/P in a community with high follow-up emphasized the importance of the CTS keeping the CHA/P's schedule open (see quote 7 in **Table 3**). Meanwhile, a CHA/P in a community with low follow-up attributed it to "bad timing," explaining that the clinic was given the referral list at the end of the school year when students were traveling for sports or in the midst of standardized testing. This CHA/P also stated that the lack of a timeline or "due date" for the completion of follow-up appointments created confusion for the clinic staff. Interviewees also described parent availability to bring their child to the clinic as a scheduling barrier (see quote 10 in **Table 3**).

Telemedicine Equipment/Processes

Interviewee feedback on telemedicine equipment and processes varied widely. The provider-facing workflow of the telemedicine specialty referral pathway was reported by some as a barrier to success in the first year of the trial, but as a facilitator in the second year of the trial after administrative modifications were made to the workflow. A CHA/P in a community which had a large decline in follow-up between year 1 and year 2 described the time consumed by back-and-forth communication between specialists and CHA/Ps as a challenge for both families and local providers (see quote 12 in **Table 3**). This provider also stated that telemedicine processes often vary across the health system's specialty care departments, and miscommunications about these processes are an issue. Another CHA/P spoke about how programs like this telemedicine specialty referral pathway get rolled out without cohesive training or clear communication to CHA/Ps. Some CHA/Ps also spoke about limitations due to technical issues with the telemedicine equipment and slow internet, which is common in these rural Alaskan communities. Two CHA/Ps in communities with high follow-up expressed concerns about patients' perceptions of telemedicine care. These providers questioned whether patients feel like they are receiving specialist care through these telemedicine appointments because they are not interacting with a specialist directly (see quote 11 in **Table 3**), and whether communication between multiple providers creates vulnerabilities for miscommunications or inaccuracies. Meanwhile, a CHA/P in a community with low follow-up spoke positively about how telemedicine processes can expedite patients' access to care (see quote 13 in **Table 3**).

Communication

Interviewees in communities with high follow-up described communication between the school and the clinic as a strength. A CTS and a CHA/P in the community with the highest follow-up noted smooth communication between the school, clinic, and parents/families. This CTS and CHA/P attributed the success of the telemedicine specialty referral pathway to the coordination of appointments by the school and clinic, instead of by the school and parents, as in the standard primary care referral pathway. In several communities with high follow-up, CHA/Ps attributed good communication with embedded community values and a mutual understanding of the process' importance at both the school and clinic (see quote 15 in **Table 3**). In a community with high follow-up, a CHA/P said that the school secretary was good at keeping lines of communication open between the school and clinic.

In communities with low and moderate follow-up, interviewees described a breakdown in communication from the clinic to parents/families. Parents' inconsistent cell phone access and transient phone numbers were described as challenges (see quote 18 in **Table 3**). One CTS cautioned that deficiencies in clinic to parent communication could have a negative impact on patients' trust in the clinic. Even in a community with high follow-up, an interviewee who is both a CHA/P and a parent described not receiving any notification from the school or clinic regarding what day their children would come to the clinic for their telemedicine specialty referral appointment. A CHA/P in a community with low follow-up spoke about the lack of information communicated to clinic staff from the Audiology department regarding the telemedicine referral pathway, and the consequent inability of clinic staff to clearly explain the referral and need for a follow-up appointment to parents.

Several teachers in communities with high and moderate follow-up noted an absence of communication from the clinic to teachers (see quote 16 in **Table 3**) and acknowledged that high teacher turnover rates may impede smooth communication from the clinic to teachers. Meanwhile, other interviewees in a community with moderate follow-up stated that health privacy regulations complicate open communication between the school and the clinic.

Awareness

In a community with high follow-up, a mutual understanding between clinic staff and school staff about the importance of follow-up was cited as a facilitator of the telemedicine specialty referral pathway. A CHA/P in this community noted that parents understand the importance of follow-up after screening referrals and bring their children in for appointments "right away" (see quote 20 in **Table 3**). In a community with low follow-up, a parent shared that witnessing the follow-up appointment was essential to increasing their personal awareness and emphasized that increasing awareness of ear and hearing issues throughout the community would be necessary to improve hearing screening follow-up (see quote 22 in **Table 3**).

Some interviewees linked the outcomes of the telemedicine pathway to parents' awareness of the importance of follow-up after a referred hearing screening. One CHA/P in a community with low follow-up attributed this to the invisibility of the need for follow-up: children who are referred from a hearing screening may not be actively "hurting" or "sick," and the need for an appointment is not immediately apparent. A CTS in a community with low follow-up emphasized the need for education to be made available for parents about the meaning of the referral and the potential consequences of untreated hearing loss (see quote 23 in **Table 3**). Meanwhile, other clinic staff asked for clear information from the Audiology department which they could use in such parent and patient education. Another provider spoke about the long timeframe of treatment pathways (including observational treatment) often inherent in ear and hearing care and worried that these timeframes created an impression of a lack of urgency or unimportance of the health condition. Regarding conceptions of hearing loss, a child spoke about stigma which may prevent children from pursuing treatment for hearing loss (see quote 21 in **Table 3**). Similarly, a parent worried that their child might be "labeled" and teased if they were on the referral list from the school screening.

DISCUSSION

The integration of qualitative and quantitative trial data is essential to understanding the factors that contribute to trial outcomes, which can then inform future implementation trials. Our trial, Hearing Norton Sound, prioritized the integration of mixed methods data. Overall, the trial demonstrated that the telemedicine specialty referral pathway profoundly increased the proportion of children receiving follow-up after school hearing screening in 15 rural Alaskan communities (previously reported in Emmett et al. 2022). When we integrated our mixed methods data and analyzed by community, we found four key factors that were associated with the success of the telemedicine specialty referral pathway: *clinic capacity, personnel ownership and engagement, communication,* and *awareness.* These four factors will be essential to incorporate in future adaptation and implementation of this telemedicine specialty referral intervention and other similar interventions in rural Alaska and beyond.

Use of mixed methods in health services research is widely recommended to counterbalance the respective limitations of qualitative and quantitative methods used in isolation and to produce findings that are better poised to be translated into practice (Glasgow & Emmons 2007; Creswell & Plano Clark 2017). Robust integration of both qualitative and quantitative domains at the design, methods, interpretation, and reporting stages can further enhance the value of mixed methods (Fetters et al. 2013; Guetterman et al. 2015). In this trial, we prioritized integration in each of these domains, and here, we report an integrated analysis using a joint display (Guetterman et al. 2015). A focus on integrated mixed methods is particularly relevant in preventive hearing health care research. Studies on hearing-related interventions often quantitatively measure follow-up (Allen et al. 2004; Hussein et al. 2018; Razak et al. 2021) and others report on barriers to follow-up or hearing health care (Kemper et al. 2004; Shulman et al. 2010; Bush et al. 2015; Gallagher & Woodside 2018), but few integrate mixed methods to better understand the factors contributing to the outcomes of a hearing-related intervention (DeJonckheere et al. 2021; Harkus et al. 2021).

An evaluation of follow-up by community revealed some variability within and between communities and study years. When aligned with community member feedback, patterns for high, moderate, and low follow-up emerged. In all communities with high follow-up, participants described ample clinic capacity, engaged personnel, consistent and clear communication, and awareness of the need for follow-up. In almost all communities with low and moderate follow-up, absences of these factors were named as barriers. In a community that had high follow-up in year 1 and low follow-up in year 2, participants described a lack of ownership by personnel, the time intensiveness of telemedicine processes, and stigma, which may have contributed to the decreased follow-up in year 2. These findings parallel what is reported elsewhere in the literature: that linkage to follow-up services can be impeded by lack of health system capacity to accommodate a high number of referrals from preventive screenings, and that poor communication between stakeholders impedes follow-up (Kimel 2006; Shulman et al. 2010). Additionally, other studies have reported that parent awareness (Skarzynski et al. 2016), stigma around hearing aid usage, and misperceptions about the importance of follow-up (Allen et al. 2004) can contribute to low follow-up. Meanwhile, community-specific feedback on scheduling and telemedicine equipment/processes did not align with community-specific follow-up proportions. This may indicate that these factors impact health care delivery at large in the region, rather than specifically influencing the intervention itself.

Findings from our study provide several areas of focus for future implementation. To address *clinic capacity*, adequate staffing or modified workflows are required for an intervention such as the telemedicine specialty referral pathway to be successful. For *personnel ownership and engagement*, staff or personnel who "own" the telemedicine referral process need to be identified and clearly tasked with seeing the process through to completion. Effective *communication* requires establishing open channels for information exchange between all stakeholders involved (health care, education, parents/caregivers). And lastly, *awareness* of the need for follow-up after referred school hearing screenings needs to be cultivated for all involved stakeholders to ensure interventions such as the telemedicine specialty referral pathway are successful. Elsewhere, we have written about how context-specific understandings of hearing health experiences can inform health education efforts to increase hearing health awareness; these and other strategies could be used to cultivate increased awareness around childhood hearing loss and the importance of follow-up after referred school hearing screenings (Inglis-Jenson et al. 2023).

There are limitations in this study that should be noted. Although the 101 interviewees included residents of all 15 communities and members of 6 stakeholder groups, this sample size is only about 1% of the region's population. We attempted to address this by purposively sampling for heterogeneity of experiences from every community and from every stakeholder group until saturation was reached. The local Alaska stakeholder team participated in the analysis, and the study team checked conclusions for relatability by presenting and discussing findings with community members during interactive community events. A second limitation is that the time periods between when interviewees experienced the intervention and when they were interviewed varied, so some participants had to recall events further in the past than others. Interviewers addressed this by incorporating a standardized narrative that explained the screening, follow-up, and intervention processes into the interview guide to facilitate participant recollections. A third limitation is potential researcher bias (Morse 2015) in both trial design and analysis. We tried to mitigate this bias by involving local members of the Alaska Stakeholder Team in iterative development of interview guides and involving team members with a wide range of backgrounds in data analysis, including an off-site qualitative research expert, onsite research staff, and local stakeholders on the Alaska Stakeholder Team.

Strengths of this mixed methods study include an in-depth analysis of trial results alongside and integrated with community member feedback, which allows for a rich understanding of the telemedicine intervention and provides direction for next steps. Currently underway are two large-scale implementation trials which will build on the work from the Hearing Norton Sound trial to test the telemedicine specialty referral pathway in new environments, both within and beyond rural Alaska (NIH Reporter Grant #: 1U01OD033247-01, 5R01DC020026-03). The results presented here have been incorporated into adaptions of the intervention for these upcoming trials. For example, in these trials, the telemedicine specialty referral intervention will occur onsite in school buildings instead of offsite in clinical

buildings in order to navigate clinic capacity limitations and reduce the complexity of communication between entities (e.g., school and hearing specialist can directly communicate regarding referral). These trials will utilize early stakeholder engagement and a mixed methods implementation-effectiveness trial design to continue refining these adaptations and ensure community partnership and engagement are central to the work.

Conclusion

Using telemedicine for specialty care access has the potential to greatly increase follow-up for school hearing screening. As future work focuses on larger-scale implementation, understanding contextual factors that are associated with the outcomes of such a referral pathway are necessary to ensure successful adoption and implementation. Our integrated analysis identified areas for consideration regarding *clinic capacity*, *personnel ownership and engagement*, *communication*, and *awareness.* It is important these areas are addressed as telemedicine interventions following referred hearing screening and other preventive health interventions are adapted, implemented, and tested in rural Alaska and beyond.

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