Article

Education and Training of Non-Genetics Providers on the Return of Genome Sequencing Results in a NICU Setting

Kelly M. East 1,*, Meagan E. Cochran 1, Whitley V. Kelley 1, Veronica Greve 1, Candice R. Finnila 1, Tanner Coleman 1, Mikayla Jennings 1, Latonya Alexander 1, Elizabeth J. Rahn 2, Maria I. Danila 2, Greg Barsh 1, Bruce Korf 3 and Greg Cooper 1

1 HudsonAlpha Institute for Biotechnology, Huntsville, AL 35806, USA; mcochran@hudsonalpha.org (M.E.C.); wkelley@hudsonalpha.org (W.V.K.); vegreve@med.umich.edu (V.G.); cfinnila@hudsonalpha.org (C.R.F.); tcoleman@hudsonalpha.org (T.C.); mjennings@hudsonalpha.org (M.J.); latonya99@gmail.com (L.A.); gbarsh@hudsonalpha.org (G.B.); gcooper@hudsonalpha.org (G.C.)
2 Division of Clinical Immunology/Rheumatology, University of Alabama at Birmingham, Birmingham, AL 35294, USA; elizabethrahn@uabmc.edu (E.J.R.); mdanila@uabmc.edu (M.I.D.)
3 Department of Genetics, University of Alabama at Birmingham, Birmingham, AL 35294, USA; bkorf@uabmc.edu
* Correspondence: keast@hudsonalpha.org; Tel.: +1-256-327-0461

Abstract: To meet current and expected future demand for genome sequencing in the neonatal intensive care unit (NICU), adjustments to traditional service delivery models are necessary. Effective programs for the training of non-genetics providers (NGPs) may address the known barriers to providing genetic services including limited genetics knowledge and lack of confidence. The SouthSeq project aims to use genome sequencing to make genomic diagnoses in the neonatal period and evaluate a scalable approach to delivering genome sequencing results to populations with limited access to genetics professionals. Thirty-three SouthSeq NGPs participated in a live, interactive training intervention and completed surveys before and after participation. Here, we describe the protocol for the provider training intervention utilized in the SouthSeq study and the associated impact on NGP knowledge and confidence in reviewing, interpreting, and using genome sequencing results. Participation in the live training intervention led to an increased level of confidence in critical skills needed for real-world implementation of genome sequencing. Providers reported a significant increase in confidence level in their ability to review, understand, and use genome sequencing result reports to guide patient care. Reported barriers to implementation of genome sequencing in a NICU setting included test cost, lack of insurance coverage, and turn around time. As implementation of genome sequencing in this setting progresses, effective education of NGPs is critical to provide access to high-quality and timely genomic medicine care.

Keywords: genetics; genome sequencing; provider education; return of results

1. Introduction

Genetic diseases are one of the leading causes of infant morbidity and mortality in the neonatal intensive care unit (NICU) [1,2]. The time it takes for an infant to receive a genetic diagnosis is often far too long to appropriately guide clinical management, highlighting the need for new advances in diagnostic technologies [3]. Multiple recent studies have established the clinical utility of genome sequencing for neonates with suspected genetic disorders, leading to increased diagnostic yield and decreased overall healthcare spending [3–8]. Despite proven clinical utility of genome sequencing in the NICU, the genetics workforce, comprised of medical geneticists and genetic counselors, is insufficient to meet current demand for genetic testing in general, especially in the southern United States [9–11], and increased usage of genetic testing will exacerbate this problem.
In response to this growing demand, the ordering and interpreting of genetic tests are increasingly provided by non-genetics providers (NGPs), who often have limited genetics knowledge in part due to limited genetics coursework offered during medical training, but also shaped by the rapidly evolving genetics landscape [12–15]. This gap in knowledge can lead to adverse medical, psychological, and financial events for patients due to inaccurate ordering, misinterpretation of results, or inadequate genetic counseling [16–18]. Neonatologists themselves report concerns about genome sequencing regarding the interpretation of results, parental consent, clinical utility of the results, and potential harms of genomic testing [19].

To meet current and expected future demand for genome sequencing in the NICU, adjustments to traditional service delivery models are necessary. These new models may include genetics professionals working in partnership with NGPs, genetics professionals providing consultative services, asynchronous oversight by genetics professionals, or the training of NGPs to effectively provide genetic services [20,21]. Effective programs for the training of NGPs have the opportunity to address known barriers to providing genetic services, including limited genetics knowledge and lack of confidence [22–24]. Previous educational interventions have been shown to increase NGP knowledge of genetics and confidence, suggesting that this type of intervention can potentially address demand for genetic services [25–28].

SouthSeq is a Clinical Sequencing Evidence-Generating Research (CSER) Consortium project exploring the use and impact of genome sequencing in NICU patients in the southeastern US [6]. A diverse population of newborn patients with suspected genetic conditions and their families were recruited from participating clinical sites in Alabama, Mississippi, Louisiana, and Kentucky. SouthSeq aims to use genome sequencing to make genomic diagnoses in the neonatal period and evaluate a scalable approach to delivering genome sequencing results to populations with limited access to genetics professionals.

2. Materials and Methods

2.1. SouthSeq Study Protocol and Purposes

Recruitment and informed consent of SouthSeq patient participants were facilitated by research nurses at each participating NICU site. Genome sequencing was performed on newborn proband samples, with Sanger confirmation of variants of interest using available parental samples [6]. Primary results (pathogenic, likely pathogenic, and uncertain) related to the newborn’s symptoms were identified and reported. Secondary results (pathogenic and likely pathogenic variants in an actionable gene list) and incidental results were also reported if the participant family consented for their return [29].

When genome sequencing and analysis were complete, results were disclosed to participant families by a study-associated healthcare provider, either in person or via telephone. Genome sequencing results were placed in the newborn’s medical record. If providers were unable to contact a participant family, certified letters were sent to notify families of result availability. A primary aim of SouthSeq is to evaluate whether genome sequencing results can be effectively communicated to patient families in the NICU setting by NGPs. SouthSeq was designed as a non-inferiority trial and participant families were randomized to either receive their genome sequencing results disclosure from a genetic counselor or a trained NICU NGP. An electronic platform, Genome Gateway (HudsonAlpha, Huntsville, AL), was utilized to communicate, provide education, and share documents with providers and participants as well as allow for digital survey completion. SouthSeq trial outcomes include parental empowerment, parental perception of uncertainty, and parental personal utility, as well as monitoring of results disclosure audio recordings for provider errors. This manuscript describes the NGP education protocol and associated outcomes of provider training. Analysis of other clinical trial data is ongoing and will be published elsewhere.

The review board at the University of Alabama at Birmingham (IRB-300000328, date of approval: 29 September 2017) approved and monitored the SouthSeq study, including
the provider training intervention. All study participants were required to give written consent to participate in this study.

2.2. Study Population

NGPs eligible for SouthSeq participation and the associated training were physicians and mid-level providers (nurse practitioners and physician assistants) working within the NICUs at five participating hospitals across Alabama, Mississippi, Louisiana, and Kentucky (Table 1). Providers either self-selected or were selected by department leadership at their institution to participate in the SouthSeq study.

Table 1. Demographic information for non-genetics neonatology providers participating in SouthSeq.

| Clinical Site                          | Frequency (%) |
|---------------------------------------|---------------|
| University of Louisville, Louisville, KY, USA | 10 (31%)      |
| Woman’s Hospital, Baton Rouge, LA, USA   | 8 (24%)       |
| University of Alabama at Birmingham, Birmingham, AL, USA | 7 (21%)     |
| University of Mississippi Medical Center, Jackson, MS, USA | 5 (15%)  |
| Children’s Hospital, New Orleans, LA, USA | 3 (9%)        |

| Race         | Frequency (%) |
|--------------|---------------|
| White        | 21 (78%)      |
| Black        | 4 (15%)       |
| Asian        | 2 (7%)        |

| Years of Experience | Frequency (%) |
|--------------------|---------------|
| 0–5 years          | 10 (37%)      |
| 6–10 years         | 4 (15%)       |
| 11–15 years        | 3 (11%)       |
| 16–20 years        | 4 (15%)       |
| 21–25 years        | 2 (7%)        |
| 25+ years          | 4 (15%)       |

2.3. Training Protocol and Objectives

The NGP training intervention was developed by a team of genetic counselors, utilizing case-based scenarios and focusing on the specific knowledge and skills needed to effectively disclose genome sequencing results. Training content and materials were developed through an iterative process, gathering feedback from members on the study team with expertise in neonatology, genetics, education, and clinical trial design. Participating NGPs were required to attend a live training session lasting approximately four hours. Training events occurred at each clinical site prior to the study launch. The training incorporated a series of brief didactic presentations, hands-on activities, and small group discussions.

Didactic topics included genome sequencing technology, SouthSeq clinical trial logistics, and psychosocial considerations. Hands-on portions of the training used a diverse set of patient and result vignettes to allow trainees to interact with example result reports that represent the variety of result implications possible through genome sequencing. The training intervention culminated with a one-on-one simulation exercise in which NICU providers reviewed and disclosed an example report to a member of the training team. The simulated results disclosure was followed by a debrief discussion between the trainee provider and genetic counselor in which real-time feedback was provided. Comprehensive genetic counseling, interpreting secondary or incidental results, and long-term medical management were considered to be out of the scope of the training intervention and expectations set for participating providers.

Learning objectives included

- Explain the benefits and limitations of genome sequencing and how it compares to other types of genetic tests;
Training materials and recorded presentations were made available online to participants for asynchronous review throughout the duration of the trial. Remote, virtual training sessions were also conducted as needed to train NGPs unable to attend the in-person training. Providers completing training remotely reviewed the recordings of didactic presentations and participated in a live interaction with a study genetic counselor to complete the discussion and simulation aspects of the training. The training intervention schedule and session descriptions can be found in Supplementary Material S1.

In addition to the live training, additional education and resources were provided to NGPs within the actual SouthSeq result reports. Reports were written in language intended to be easily understood by both NGPs and participant families. Report format and verbiage were generated via an iterative process and consultation with experts in health literacy. Reports include a bulleted list of key points about the result including the possible impact of the results on medical care and family members. This “just-in-time” education was specific to a particular patient result and delivered at the time the provider would be using the information to talk with families and guide medical care. An example SouthSeq result report can be found in Supplementary Material S2.

2.4. Survey Instrumentation

Prior to live training, participating providers completed an online pre-survey. The pre-survey elicited demographic information, current practices regarding genetic and genomic testing, and baseline confidence in understanding genome sequencing results and using genome sequencing results to manage patient care. An online post-survey was completed immediately following the live training intervention. The post-survey included questions regarding the impact of training on increasing relevant knowledge and skills for genome sequencing result disclosure. Response options included a Likert scale of “not at all,” “a little,” “somewhat,” and “very.” The confidence questions from the pre-survey were repeated on the post-survey to measure the change in reported confidence related to participation in the training intervention. The Wilcoxon signed-ranks test was used to analyze pre- and post-confidence levels of matched samples. Finally, the post-survey included a series of open-ended questions for providers to give feedback regarding the most and least useful aspects of training and any additional topics for which they would like to receive education and training. Survey questions were novel and developed by the study team. Survey instruments can be found in Supplementary Material S2.

3. Results

3.1. SouthSeq Non-Genetics Provider Participants

3.1.1. Demographics

A total of 33 neonatology non-genetics providers received training across the 5 clinical sites, including 26 physicians and 7 nurse practitioners. Twenty-seven providers completed the pre-training survey (Table 1). The majority of respondents were white (78%) and early in their career (0–10 years of experience, 52%). More than half (54%) reported no previous formal genetics training. Those who reported previous genetics education described
that education as a residency rotation (37%), a genetics course or continuing medical education (CME) (11%), a genetics residency or fellowship (4%), or other experiences (4%). Selection of participating providers varied among clinical sites based on a variety of factors, including provider interest and clinical capacity. Therefore, the demographics of participating providers are not necessarily representative of the larger NICU clinical teams at each clinical site.

3.1.2. Prior Experience with Genetic and Genomic Testing

Prior to SouthSeq training, providers reported that they order genetic tests approximately once per week (33%), once per month (48%), or once per year (19%). The pre-survey elicited self-reported confidence in the abilities to read and interpret genetic test results (i.e., single gene tests and gene panel tests), read and interpret genome sequencing results, and manage a patient’s care based on genome sequencing results. Compared to confidence reading and interpreting genetic test results and managing patients based on genome sequencing results, NGPs expressed the lowest confidence in their ability to read and interpret genome sequencing results; 78% of NGPs reported that they were a little confident or not at all confident in this domain, with no NGPs stating that they were very confident in this area (Figure 1). Further, 66% of respondents reported they had never seen a genome sequencing result in their clinical practice.

![Figure 1](image_url)

**Figure 1.** Baseline, self-reported confidence levels prior to attending SouthSeq provider training intervention related to ability to read and interpret genetic test results, ability to read and interpret genome sequencing results, and managing a patient’s care based on genome sequencing results.

The pre-survey also elicited perceptions of barriers to implementation of genome sequencing in the NICU setting. Respondents selected from a pre-defined list of barriers, with the ability to select multiple responses. The pre-defined list was generated by the study team, with an option for respondents to add other barriers not included on the list. The most frequent barriers selected being test cost (81%), lack of insurance coverage (81%), turnaround time (81%), and lack of healthcare provider knowledge/training (56%) (Table 2). In contrast, no respondents indicated that no barriers existed and only 7% cited a lack of diagnostic value as a barrier for implementation of genome sequencing.
The final section of the post-training survey elicited feedback from participants about the perceived impact of the training intervention. Respondents were asked to select to what extent training increased their understanding of genomics and the role it can play in making a diagnosis. Respondents mostly indicated that the training intervention had a positive impact on this understanding, answering “very” ($n = 11.48\%$), “somewhat” (11.48\%), and “a little” (1.4%). The survey also asked respondents to select to what extent training equipped them with the knowledge and skills needed to implement the provider role in SouthSeq. Respondents indicated a positive impact of training, with the majority of respondents (18.78\%) selecting the “very” option, with the remaining respondents selecting “somewhat.”

### 3.2. Impact of the SouthSeq Training Intervention

#### 3.2.1. Provider Understanding and Skills

Twenty-three providers completed the post-training survey. The post-training survey elicited feedback from participants about the perceived impact of the training intervention. Respondents were asked to select to what extent training increased their understanding of genomics and the role it can play in making a diagnosis. Respondents mostly indicated that the training intervention had a positive impact on this understanding, answering “very” ($n = 11.48\%$), “somewhat” (11.48\%), and “a little” (1.4%). The survey also asked respondents to select to what extent training equipped them with the knowledge and skills needed to implement the provider role in SouthSeq. Respondents indicated a positive impact of training, with the majority of respondents (18.78\%) selecting the “very” option, with the remaining respondents selecting “somewhat.”

#### 3.2.2. Provider Confidence

Following the training intervention, providers were asked to re-evaluate their perceived confidence in their ability to read and interpret genome sequencing results (Figure 2), as well as confidence in managing a patient’s care based on genome sequencing results (Figure 3). Confidence ratings increased in both domains after participating in SouthSeq provider training. The post-test median response for each of these questions was “some-

### Table 2. Perceived barriers to implementation of genome sequencing in the NICU setting.

| Barrier                                      | n (%)  |
|----------------------------------------------|--------|
| Test cost                                    | 22 (81\%) |
| Lack of insurance coverage                   | 22 (81\%) |
| Turnaround time                              | 22 (81\%) |
| Lack of healthcare provider knowledge/training| 15 (56\%) |
| Possibility of uncertain results              | 13 (48\%) |
| Possibility of unexpected results             | 9 (33\%) |
| Limited healthcare provider time             | 3 (11\%) |
| Limited diagnostic value                     | 2 (7\%) |
| Other                                        | 0 (0\%) |
| There are no barriers                        | 0 (0\%) |

#### 3.3. Qualitative Feedback

The final section of the post-training survey elicited feedback from participants about the perceived impact of the training intervention. Respondents were asked to select to what extent training increased their understanding of genomics and the role it can play in making a diagnosis. Respondents mostly indicated that the training intervention had a positive impact on this understanding, answering “very” ($n = 11.48\%$), “somewhat” (11.48\%), and “a little” (1.4%). The survey also asked respondents to select to what extent training equipped them with the knowledge and skills needed to implement the provider role in SouthSeq. Respondents indicated a positive impact of training, with the majority of respondents (18.78\%) selecting the “very” option, with the remaining respondents selecting “somewhat.”

### Figure 2. Comparison of self-reported provider confidence before and after participating in SouthSeq training about ability to read and interpret genome sequencing results.
3.3. Qualitative Feedback

The final section of the post-training survey elicited free-text responses regarding the most and least valuable aspects of the training intervention. Eleven respondents (48%) reported that the simulated results disclosure with genetic counselors was the most valuable aspect of training. Other aspects of training mentioned in free-text responses as being most valuable included reviewing example result reports, understanding what genome sequencing does, and being able to ask questions about the study protocol. Most respondents (18/23) did not mention any specific training aspects that were least valuable. However, a minority of respondents mentioned they found the didactic portions of training to be least valuable. Four respondents provided feedback on additional topics they wish had been covered, or covered in more depth, as a part of training. These topics included more information about incidental findings, different types of genetic testing, and genome sequencing.

4. Discussion

The SouthSeq study aimed to explore the diagnostic utility of genome sequencing in a diverse population of patients in a NICU setting and test a scalable approach to the implementation of genome sequencing. SouthSeq and other related studies have established the clinical utility of genome sequencing for neonates with suspected genetic disorders, leading to increased diagnostic yield and decreasing overall healthcare spending [3–6]. However, current workforce shortages of medical geneticists and genetic counselors, the skewed geographic distribution of genetics providers, and limited genetics knowledge among NGPs hinder the widespread implementation of genome sequencing in the NICU setting [9–11,23]. To aid in addressing these barriers, the SouthSeq study tested a scalable model of genome sequencing results disclosure by trained non-genetics providers. As a part of this model, neonatology NGPs received live, interactive training by a team of genetic counselors and were provided with enduring educational resources.

Participation in the live training intervention led to an increased level of confidence in critical skills for the clinical implementation of genome sequencing. Providers reported a significant increase in confidence level in their ability to review, understand, and use genome sequencing result reports to guide patient care. Providers also reported gains in knowledge regarding the use of genomics in making diagnoses and the role of the NGP.
within the SouthSeq project specifically. These outcomes, while unique in technology
used and clinical context, are in line with the outcomes observed in other successful NGP
genetics training interventions [25,26].

When asked to evaluate the most useful components of the training protocol, nearly
half of participants identified the value of the interactive and practical components, includ-
ing simulated results disclosures and reviewing example reports, while a small minority
found didactic components to be least valuable. Prior studies have indicated that problem-
based learning and interactive learning interventions such as the one described in this
manuscript are effective in improving the knowledge of genetics and clinical skills of
NGPs and are training modalities that are favored by NGPs [26,27,31]. Although studies
suggest that these forms of continuing medical education (CME) are effective, substantial
barriers remain to widespread adoption including provider time, financial considerations,
preference for other methods or content of CME, lack of awareness of genetics CME, and
the geographical distance of CME offerings from provider practice location [32,33]. Addition-
ally, genetics education interventions such as the one explored in this study require a
substantial investment of time and resources by genetics experts to develop content, create
resources, and facilitate training sessions.

Despite a growing body of evidence demonstrating clinical utility, genome sequencing
remains an infrequently used diagnostic test in NICUs [34]. Data presented here provide
insight into perceived barriers among NICU NGPs regarding the implementation of genome
sequencing. Few surveyed providers reported lack of diagnostic value as a barrier. A larger
minority of respondents cited unexpected and uncertain results as an implementation
barrier. These findings are similar to the NICU provider perspectives identified in other
studies [19]. Logistical issues including cost, lack of insurance coverage, and turnaround
time were reported to be barriers by most respondents. These logistical barriers may be
overcome in the future as genome sequencing technology improves and the evidence for
clinical utility continues to grow. More than half of respondents selected a lack of provider
knowledge and training as a barrier to genome sequencing implementation, a finding in
line with other publications [35].

The training intervention described in this study and its preliminary outcomes demon-
strate the value of genetic counselors and other genetics experts as educators of NGPs,
a role echoed in genetic counselor practice-based competencies and often reported as a
component of job duties [36,37]. Due to limited access to genetics specialists, adjustments
to traditional service delivery models are critical, which may include educating NGPs
to provide genetic services as in the SouthSeq study or other models such as genetics
professionals working in tandem with NGPs or genetics professionals providing consulta-
tive services [20]. In the future, additional data surrounding the outcomes of disclosure
of genome sequencing results by NGPs in the SouthSeq study will be made available,
including data on the frequency and nature of errors in results disclosure and comparisons
to disclosure of results by genetic counselors. Further research is needed to evaluate the
outcomes of the implementation of this novel service delivery model and its ability to
provide access to accurate, effective, and timely genetic testing and counseling services.

The interpretation of our study findings are limited by a relatively small sample of
NGPs. Due to the limited sample size, we were unable to assess the effect of provider
demographic variables on outcome data. The training intervention described and tested
would benefit from additional study in a larger population of NGPs and in additional
clinical contexts beyond the NICU. Opportunities for future research include assessing
whether the increased levels of provider confidence observed post-training are sustained
over time and whether participation in SouthSeq had an impact on the use of genome
sequencing by participating providers and institutions, as well as other measures of objective
impact. Measuring outcomes based on perceived confidence is limited by its subjective and
potentially transient nature, particularly in the setting of acutely ill infants.

Herein, we describe the protocol for a live, interactive educational intervention utilized
in the SouthSeq study and the associated impact on NGP knowledge and confidence in
reading, interpreting, and using genome sequencing results. As the body of evidence for the diagnostic utility of genome sequencing in critically ill newborns grows, utilization of genome sequencing is expected to increase, placing a higher demand on NGPs to facilitate this testing. As implementation of genome sequencing in this setting progresses, effective education of NGPs is critical to provide access to high-quality and timely genomic medicine care.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/jpm12030405/s1, S1: SouthSeq provider training schedule; S2: SouthSeq provider training survey instruments; Table S3: Survey data.

Author Contributions: Conceptualization, K.M.E., M.E.C., W.V.K., V.G., C.R.F., E.J.R., M.I.D., G.B., B.K. and G.C.; methodology, K.M.E., M.E.C., W.V.K., V.G., C.R.F., E.J.R., M.I.D., G.B., B.K. and G.C.; formal analysis, K.M.E. and M.C; investigation, K.M.E., M.E.C., W.V.K., V.G., C.R.F., E.J.R. and M.I.D.; resources, K.M.E., M.E.C., W.V.K., V.G., C.R.F. and E.J.R.; data curation, K.M.E. and M.E.C.; writing—original draft preparation, K.M.E., T.C., M.J. and L.A.; writing—review and editing, K.M.E., M.E.C., W.V.K., V.G., C.R.F., T.C., M.J., L.A., E.J.R., M.I.D., G.B., B.K. and G.C.; visualization, K.M.E., M.E.C. and T.C.; supervision, K.M.E., G.B., B.K. and G.C.; project administration, C.R.F., M.I.D., G.B., B.K. and G.C.; funding acquisition, G.B., B.K. and G.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research (grant number U01HG007301) was supported by the Clinical Sequencing Evidence-Generating (CSER) consortium funded by the National Human Genome Research Institute (NHGRI) with co-funding from the National Institute on Minority Health and Health Disparities (NIMHD) and the National Cancer Institute (NCI).

Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of the University of Alabama at Birmingham (protocol code IRB-30000328, 29 September 2017).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The data presented in this study are available in Supplementary Material Table S3.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References
1. Soneda, A.; Teruya, H.; Furuya, N.; Yoshihashi, H.; Enomoto, K.; Ishikawa, A.; Matsui, K.; Kurosawa, K. Proportion of malformations and genetic disorders among cases encountered at a high-care unit in a children’s hospital. Eur. J. Pediatr. 2011, 171, 301–305. [CrossRef] [PubMed]
2. Stevenson, D.A.; Carey, J.C. Contribution of malformations and genetic disorders to mortality in a children’s hospital. Am. J. Med. Genet. Part A 2004, 126, 393–397. [CrossRef] [PubMed]
3. Willig, L.; Petrikin, J.E.; Smith, L.D.; Saunders, C.J.; Thiffault, J.; Miller, N.A.; Soden, S.E.; Cakici, J.; Herd, S.M.; Twist, G.; et al. Whole-genome sequencing for identification of Mendelian disorders in critically ill infants: A retrospective analysis of diagnostic and clinical findings. Lancet Respir. Med. 2015, 3, 377–387. [CrossRef]
4. Dimmock, D.P.; Clark, M.M.; Gaughran, M.; Cakici, J.A.; Caylor, S.A.; Clarke, C.; Feddock, M.; Chowdhury, S.; Salz, L.; Cheung, C.; et al. An RCT of Rapid Genomic Sequencing among Seriously Ill Infants Results in High Clinical Utility, Changes in Management, and Low Perceived Harm. Am. J. Hum. Genet. 2020, 107, 942–952. [CrossRef] [PubMed]
5. Sweeney, N.M.; Nahas, S.A.; Chowdhury, S.; Batalov, S.; Clark, M.; Caylor, S.; Cakici, J.; Nigro, J.J.; Ding, Y.; Veeraraghavan, N.; et al. Rapid whole genome sequencing impacts care and resource utilization in infants with congenital heart disease. NPJ Genom. Med. 2021, 6, 29. [CrossRef]
6. Bowling, K.M.; Thompson, M.L.; Finnila, C.R.; Hiatt, S.M.; Latner, D.R.; Amaral, M.D.; Lawlor, J.M.; East, K.M.; Cochran, M.E.; Greve, V.; et al. Genome sequencing as a first-line diagnostic test for hospitalized infants. Genet. Med. 2021, 23, 1054–1065. [CrossRef] [PubMed]
7. Smith, L.D.; Willig, L.K.; Kingsmore, S.F. Whole-Exome Sequencing and Whole-Genome Sequencing in Critically Ill Neonates Suspected to Have Single-Gene Disorders. Cold Spring Harb. Perspect. Med. 2016, 6, a023168. [CrossRef]
8. Vassy, J.L.; Lautenbach, D.M.; McLaughlin, H.M.; Kong, S.W.; Christensen, K.D.; Krier, J.; Kohane, I.S.; Feuerman, L.Z.; Blumenthal-Barby, J.; Roberts, J.S.; et al. The MedSeq Project: A randomized trial of integrating whole genome sequencing into clinical medicine. *Trials* **2018**, *15*, 85. [CrossRef]

9. Maiese, D.R.; Keehn, A.; Lyon, M.; Flannery, D.; Watson, M. Current conditions in medical genetics practice. *Genet. Med.* **2019**, *21*, 1874–1877. [CrossRef]

10. Hoskovec, J.M.; Bennett, R.L.; Carey, M.E.; DaVanzo, J.E.; Dougherty, M.; Hahn, S.E.; LeRoy, B.S.; O’Neal, S.; Richardson, J.G.; Wicklund, C.A. Projecting the Supply and Demand for Certified Genetic Counselors: A Workforce Study. *J. Genet. Couns.* **2018**, *27*, 16–20. [CrossRef]

11. Villegas, C.; Haga, S.B. Access to Genetic Counselors in the Southern United States. *J. Pers. Med.* **2019**, *9*, 33. [CrossRef] [PubMed]

12. Shields, A.E.; Burke, W.; Levy, D.E. Differential use of available genetic tests among primary care physicians in the United States: Results of a national survey. *Genet. Med.* **2008**, *10*, 404–414. [CrossRef] [PubMed]

13. Greendale, K.; Pyeritz, R.E. Empowering primary care health professionals in medical genetics: How soon? How fast? How far? *Am. J. Med Genet.* **2001**, *106*, 223–232. [CrossRef] [PubMed]

14. Plunkett-Rondeau, J.; Hyland, K.; Dasgupta, S. Training future physicians in the era of genomic medicine: Trends in undergraduate medical genetics education. *Genet. Med.* **2015**, *17*, 927–934. [CrossRef] [PubMed]

15. Dasgupta, S.; Feldman, G.L.; Powell, C.M.; Toriello, H.V.; Westman, J.; Wilson, W.G.; Waggoner, D.J. Training the next generation of genomic medicine providers: Trends in medical education and national assessment. *Genet. Med.* **2020**, *22*, 1718–1722. [CrossRef] [PubMed]

16. Bensend, T.A.; Veach, P.M.; Niendorf, K.B. What’s the Harm? Genetic Counselor Perceptions of Adverse Effects of Genetic Service Provision by Non-Genetic Professionals. *J. Genet. Couns.* **2013**, *23*, 48–63. [CrossRef]

17. Brierley, K.L.; Blouch, E.; Cogswell, W.; Homer, J.P.; Pencarina, D.; Stanislaw, C.L.; Matloff, E.T. Adverse Events in Cancer Genetic Testing: Medical, Ethical, Legal, and Financial Implications. *Cancer J.* **2012**, *18*, 303–309. [CrossRef]

18. Farmer, M.B.; Bonadies, D.C.; Mahon, S.M.; Baker, M.J.; Ghate, S.M.; Munro, C.; Nagaraj, C.B.; Besser, A.G.; Bui, K.; Csuy, C.M.; et al. Errors in Genetic Testing: The Fourth Case Series. *Cancer J.* **2019**, *25*, 231–236. [CrossRef]

19. Knapp, B.; Decker, C.; Lantos, J.D. Neonatologists’ Attitudes about Diagnostic Whole-Genome Sequencing in the NICU. *Pediatrics* **2019**, *143*, S54–S57. [CrossRef]

20. Stoll, K.; Kubendran, S.; Cohen, S.A. The past, present and future of service delivery in genetic counseling: Keeping up in the era of precision medicine. *Am. J. Med Genet. Part C Semin. Med Genet.* **2018**, *178*, 24–37. [CrossRef]

21. Booth, E.; West, B.; Hendon, L.G.; Kaplan, J.D.; Kirmse, B. Asynchronous telemedicine for clinical genetics consultations in the NICU: A single center’s solution. *J. Perinatol.* **2021**, *42*, 262–268. [CrossRef] [PubMed]

22. Sutter, S.; Goodson, P. Barriers to the provision of genetic service by primary care physicians: A systematic review of the literature. *Genet. Med.* **2005**, *5*, 70–76. [CrossRef] [PubMed]

23. Hamilton, J.G.; Abdwiawah, E.; Edwards, H.M.; Fang, M.-L.; Jdayani, A.; Breslau, E.S. Primary care providers’ cancer genetic testing-related knowledge, attitudes, and communication behaviors: A systematic review and research agenda. *J. Gen. Intern. Med.* **2017**, *32*, 315–324. [CrossRef] [PubMed]

24. Dekanek, E.W.; Thull, D.L.; Massart, M.; Grubs, R.; Rajkovic, A.; Mai, P.L. Knowledge and opinions regarding BRCA1 and BRCA2 genetic testing among primary care physicians. *J. Genet. Couns.* **2019**, *29*, 122–130. [CrossRef]

25. Wilkes, M.S.; Day, F.C.; Fancher, T.L.; McDermott, H.; Lehman, E.; Bell, R.A.; Green, M.J. Increasing confidence and changing behaviors in primary care providers engaged in genetic counselling. *BMC Med. Educ.* **2017**, *17*, 163. [CrossRef]

26. Cornel, M.C. Evidence-Based Genetic Education of Non-Genetic-Expert Physicians: Experiences Over Three Decades in Amsterdam. *Front. Genet.* **2019**, *10*, 712. [CrossRef]

27. Jackson, L.; O’Connor, A.; Paneque, M.; Curtisova, V.; Lunt, P.W.; Pourouva, R.K.; Macek, M.; Stefansdottir, V.; Turchetti, D.; Campos, M.; et al. The Gen-Equip Project: Evaluation and impact of genetics e-learning resources for primary care in six European languages. *Genet. Med.* **2018**, *21*, 718–726. [CrossRef]

28. Campion, M.; Goldgar, C.; Hopkin, R.J.; Prows, C.A.; Dasgupta, S. Genomic education for the next generation of health-care providers. *Genet. Med.* **2019**, *21*, 2422–2430. [CrossRef]

29. Miller, D.T.; Lee, K.; Chung, W.K.; Gordon, A.S.; Herman, G.E.; Klein, T.E.; Stewart, D.R.; Amendola, L.M.; Adelman, K.; Bale, S.J.; et al. ACMG SF v3.0 list for reporting of secondary findings in clinical exome and genome sequencing: A policy statement of the American College of Medical Genetics and Genomics (ACMG). *Genet. Med.* **2021**, *23*, 1381–1390. [CrossRef]

30. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates: Hillsdale, NJ, USA, 1988.

31. Metcalfe, S.; Hurworth, R.; Nevestead, J.; Robins, R. Needs assessment study of genetics education for general practitioners in Australia. *Genet. Med.* **2002**, *4*, 71–77. [CrossRef]

32. Barnabé, C.; Kirk, P. A Needs Assessment for Southern Manitoba Physicians for Palliative Care Education. *J. Palliat. Care* **2002**, *18*, 175–184. [CrossRef] [PubMed]

33. Botes, J.; Bezuidenhout, J.; Steinberg, W.J.; Joubert, G. The needs and preferences of general practitioners regarding their CPD learning: A Free State perspective. *S. Afr. Fam. Pract.* **2016**, *58*, 114–118. [CrossRef]

34. Stark, Z.; Nisselle, A.; McClaren, B.; Lynch, F.; Best, S.; Long, J.C.; Martyn, M.; Patel, C.; Schlalpbach, L.J.; Barnett, C.; et al. Attitudes of Australian health professionals towards rapid genomic testing in neonatal and paediatric intensive care. *Eur. J. Hum. Genet.* **2019**, *27*, 1493–1501. [CrossRef] [PubMed]
35. Franck, L.S.; Kriz, R.M.; Rego, S.; Garman, K.; Hobbs, C.; Dimmock, D. Implementing Rapid Whole-Genome Sequencing in Critical Care: A Qualitative Study of Facilitators and Barriers to New Technology Adoption. *J. Pediatr.* 2021, 237, 237–243. [CrossRef]

36. Accreditation Council for Genetic Counseling Practice-based Competencies for Genetic Counselors. 2019. Retrieved 15 December 2021. Available online: https://www.gceducation.org/practice-based-competencies/ (accessed on 1 January 2022).

37. National Society of Genetic Counselors Professional Status Survey 2021: Work Environment. 2021. Retrieved 15 December 2021. Available online: https://www.nsgc.org/Policy-Research-and-Publications/Professional-Status-Survey (accessed on 1 January 2022).