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ARTICLE

Exploring current challenges in the technologist workforce of clinical genomics laboratories

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ABSTRACT

Purpose: Workforce shortages are observed in many sectors of the economy, including clinical genomics laboratories. Although medical technologists are essential for the primary functions of laboratory operations and many institutions in the United States have reported acute staff shortages, we are unaware of any recent studies that provide concrete data detailing workforce needs. In this report, we summarize the results of a technologist-based survey sent to clinical laboratory directors across the United States.

Methods: The survey was designed to provide detailed and objective evidence on the current landscape of the technologist workforce in clinical cytogenetics, molecular genetics, and laboratories that have combined both disciplines. Survey questions included demographics, salaries across career stages, retention trends, and hiring requirements and challenges.

Results: Analysis of the survey data from 70 US-based submissions showed that cytogenetics laboratories had higher proportion of unfilled technologist positions, whereas molecular laboratories had more applications for each open positions. The technologist retention rate in molecular laboratories was higher than that in cytogenetics. The lack of adequately trained applicants and competitive salary offers by other laboratories were cited as top barriers for filling technologist positions.

Conclusion: The results from this survey will serve as normative data in generating solutions to address acute workforce needs in the United States.

Introduction

Since 2021, workers across all sectors around the world were resigning from their employment *en masse*; this was referred to as "The Great Resignation".[1,2] Studies have shown that workers, who left a job in 2021, cited low pay and no opportunities for advancement as the top reasons.[3] In the laboratory setting, workforce shortage was also observed for post doctoral fellows and technologists.[4-7] These observations occurring for both postdocs and technologists are

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likely because of different reasons, and they will have different consequences: scarcity of post doctoral fellows will lead, among others, to a shortage in clinical laboratory directors in the future and a negative impact on the advancement of science, whereas shortage of technologists results in immediate strain on laboratory productivity and ultimately on patient care.[4-6,8,9]

In clinical genomics laboratories in the United States, technologists, who have Bachelor's degrees, use highly specialized techniques, ranging from chromosome banding to next generation sequencing, to identify the genetic causes of human diseases and are, hence, considered essential workers in a high complexity testing environment. Depending on the states or hospitals, additional certifications for technologists may be required. Of note, the "technician" job title is generally referred to laboratory personnel without Bachelor's degrees and is distinctly different from technologists. In contrast, clinical laboratory directors in the United States are required by the Centers for Medicare and Medicaid Services to hold a doctoral degree in a chemical, physical, biological, or clinical laboratory science as well as certified by a board approved by the United States Department of Health and Human Services. Clinical laboratory directors are responsible for and/or oversees the overall operation and administration of a clinical laboratory. This role may include the management of appropriate trained and qualified personnel, laboratory assurance, result interpretation, and test reporting.

In recent professional society annual meetings (ie, The American College of Medical Genetics and Genomics, American Cytogenomics Conference, and Cancer Genomics Consortium) as well as email listserv forums, clinical genomic laboratory directors have discussed the growing technologist workforce shortage, the consequences of which invariably lead to delays in testing, directly affecting accurate and timely patient care, experience, and outcomes. Despite the increased awareness of this crisis, little has been published to inform the fundamental reasons behind this shortage. Although it may be because of many factors, including lack of adequately trained applicants, competing salary offers between academic centers and industry, lack of awareness of the field and educational opportunities, lack of career advancement, etc., there have not been any recent studies accurately detailing staff shortage in US-based clinical genomics laboratories, especially since the onset of COVID-19. It is well recognized that the COVID-19 pandemic has put a big strain on laboratory operations and has surely brought this issue to the surface.[5] Based on these facts, the field has become acutely aware that a comprehensive study is needed to construct thoughtful solutions that will aid in addressing this impending crisis. In this study, we summarize the result of a US-based survey that was targeted to the directors of clinical molecular and cytogenetic laboratories and provide initial data that shed light on the possible causes of the technologist shortage in the United States.

Materials and Methods

The survey was developed by American Board of Medical Genetics and Genomics (ABMGG)-boarded laboratory geneticists (Y.A., S.D., R.G.B., and M.L.L.) after initial discussions with 11 other laboratory directors at the 2022 American College of Medical Genetics and Genomics Annual Meeting in Nashville. The questions in this survey were developed by the authors, who have extensive expertise in clinical laboratory operations and leadership, to specifically collect detailed evidence required to understand the current landscape of technologist workforce needs. The survey was distributed using SurveyMonkey and was open for responses for 6 weeks (Supplemental Document). The survey was targeted to the directors of Clinical Laboratory Improvement Amendments-certified laboratories located in the United States who performed germline and/or cancer genomics testing. Laboratory directors were identified using the Genetic Testing Registry (GTR) through the National Library of Medicine (https://www.ncbi.nlm.nih.gov/gtr/) and met the following inclusion criteria: human disease testing, laboratory located in the U.S., and Clinical Laboratory Improvement Amendments certification. This GTR search query, performed on May 5th, 2023, yielded 198 laboratories. The list of the laboratory directors was compiled if the email addresses were available on the GTR registry. Laboratory directors were also identified through the authors' professional connections. In total, the email with the survey link was sent to more than 330 laboratory directors on July 5th, 2022. In addition, and in order to reach a broader audience, the survey was also announced on the American Cytogenomics Conference email listserv (which includes more than 640 email addresses of genomic laboratory professionals) on July 11th, 2022. The survey entries were compiled and analyzed to make sure only one survey entry was documented per laboratory. The names of the laboratory respondents are kept confidential and are not part of the published data to maintain anonymity.

The data were analyzed using Microsoft Excel (Microsoft Corporation, Redmond, WA). Statistical calculation was performed in Prism Graphpad (Graphpad Software, Boston, MA). Unpaired *t*-test and Welch's analysis of variance test were used to calculate statistical differences. Open ended comments were categorized by Y.A.

This survey was assessed by the Nationwide Children's Hospital Institutional Review Board and was deemed to be exempt.

Results

A total of 91 entries were initiated on the demographic questions in the survey. Of these, 70 had answered at least some portion of the workforce questions and were ultimately used for downstream analysis. Results showed that the respondents were evenly distributed across the United

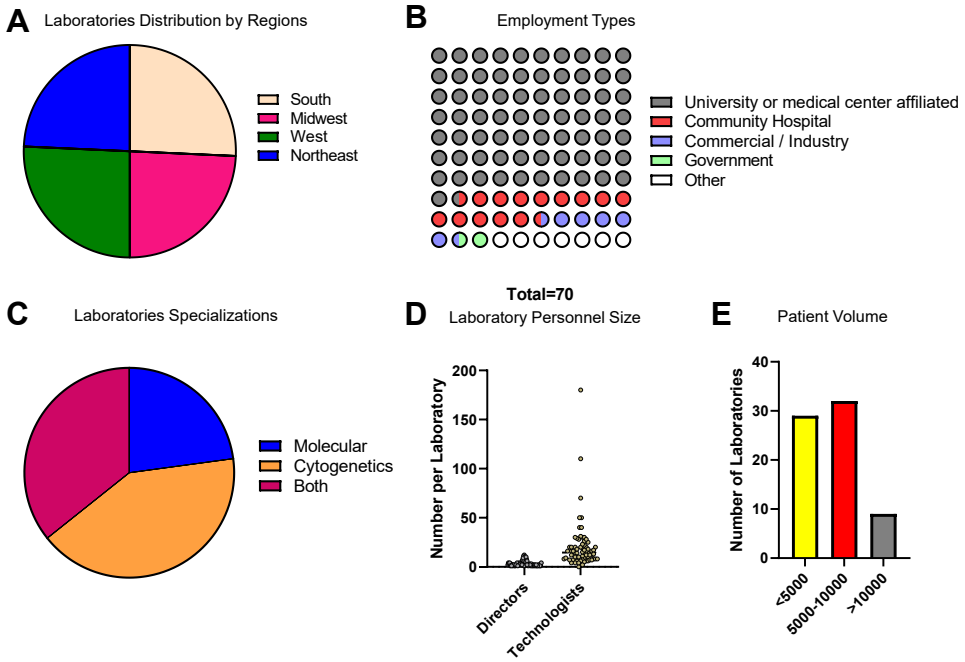

Figure 1 Demographics of laboratory respondents. (A) Of the 70 laboratories that were included in the analysis of this study, 17 were in the Northeast region, 18 South, 17 Midwest, and 18 West. (B) 50 laboratories were university or medical center affiliated, 10 community hospitals, 4 commercial/industry, 1 government, and 5 others. (C) The testing specialties of the laboratories are molecular (n = 16), cytogenetics (n = 29), and both (n = 25). (D) The median number of directors per lab is 3.2, and the median of technologists is 14.5. (E) 41% laboratories had <5000 patient volume per year, 46% had 5000-10,000, and 13% had >10000.

States (Figure 1A; See Supplemental Table 1 for the U.S. Census Bureau definition for Northeast, Midwest, South, and West). No entries were submitted from Hawaii or Alaska. The majority of the laboratories (71%, 50/70) were affiliated with a university or medical center, with the second most common being community hospitals (14%, 10/70) (Figure 1B). 23% laboratories (16/70) were specialized in molecular, 41% (29/70) in cytogenetics, and 36% (25/70) specialized in both (Figure 1C). In this cohort, the mean number of directors per laboratory was 3.2 (median = 2.0, standard deviation = 2.76), whereas the mean number of technologists was 20.6 (median = 14.5, standard deviation = 25.46) (Figure 1D). 41% laboratories (29/70) had <5000 patient volume per year, 46% (32/70) had 5000-10,000, and 13% (9/70) had >10,000 (Figure 1E).

We surveyed the base salary for 3 categories of technologists: entry-level, at least 5 years of experience, and at least 10 years of experience. A total of 64 respondents provided data for at least 1 category. On an average, the base salaries for entry-level, 5 years, and 10 years of experience are $61,647 (SD = 20,528), $73,950 (SD = 22,394), and $86,929 (SD = 26,674), respectively (Figure 2A), when stratified by regions, the entry-level base salary rank from West (mean = 78,691; SD = 26,193), Northwest (mean = 63,268; SD = 16,522), Midwest (mean = 55,425; SD = 55,425), and South (mean = 49124; SD = 9852) (Figure 2B). Laboratory types did not have appreciable differences in starting salaries (Figure 2C). Additionally, no appreciable differences in entry-level salary were observed when stratified by employment types and patient volume. Only 42.8% of all laboratories (27/63) offer sign-on bonuses.

Next, we asked the length of employment for the last 3 technologists who left the laboratory. 67 laboratories provided data that added up to 186 positions. On an average, technologists were retained for 7.49 years (SD = 8.50) (Figure 3A). When comparing the 2 disciplines, molecular technologists were retained for the shortest time at 3.68 years (n = 44; SD = 3.14), whereas cytogenetic technologists were retained longest at 9.56 years (n = 75; SD = 8.49) (Figure 3B). Technologist retention based on regions ranged from 6.04 years in Midwest to 9.02 years in West, with no significant differences among the regions (P-value = .2908, Welch analysis of variance test) (Figure 3C). We surveyed the top reason the technologists cited for leaving their positions. Approximately, 30% cited "another job offer with higher salary" (20/67), followed by "pursue of further education or training" (12/67), and "loss of interest or dissatisfaction in the position" (7/67). Of note, 31% of respondents cited "other" as the top reason (Figure 3D).

We surveyed the number of open positions in the past 2 years. Of the 70 laboratories that provided data, the average number of open positions was 4.24 (range = 0-32, median = 3). (Figure 4A). No appreciable trends were observed when stratified by laboratory types and regions (Figure 4B), which indicated that the technologist shortage is universal across all genomics laboratories. Next, we asked the length of time needed to fill a position. In total, we obtained data for 183

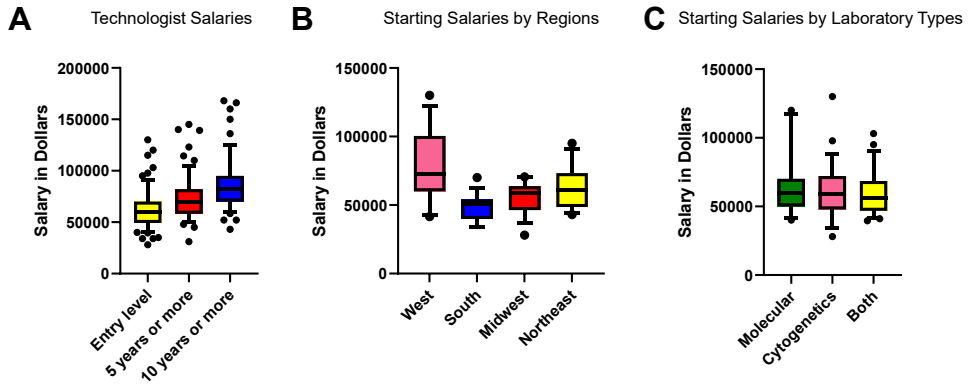

Figure 2 Salaries for technologists. (A) In this cohort, the average salaries for technologists at entry level, 5 years of experience, and 10 years of experience were $61,647, $73,950, and $86,929, respectively. (B) When stratified by regions, West had the highest salary on average for entry level ($78,691), compared with Northwest ($63,268), Midwest ($55,425), and South ($49,124). (C) Laboratory specialties did not have significant differences in starting salaries (*P*-value = .7642, Welch's analysis of variance test).

positions from 67 laboratories. For the 125 filled positions, it took an average of 16.5 weeks (median = 12) to fill. 31.7% positions (58/183) were reported to be unfilled. Among this cohort, molecular positions only had 10.5% (4/38) unfilled positions, cytogenetic positions 31% (24/77), and combined positions 44% (30/68) (Figure 4C). When stratified by regions, laboratories in the Northeast had the highest unfilled positions at 62.8% (27/43), followed by the South at 30.4% (14/46), Midwest at 24.4% (11/45), and West at 12.2% (6/49).

We surveyed the number of applications per position. Of the 68 respondents, each position had an average of 4.29 applications (median = 3). When stratified by laboratory types, molecular positions had more applications (average = 6.73; median = 5), compared with cytogenetics (average = 3.38; median = 3) and combined (average =

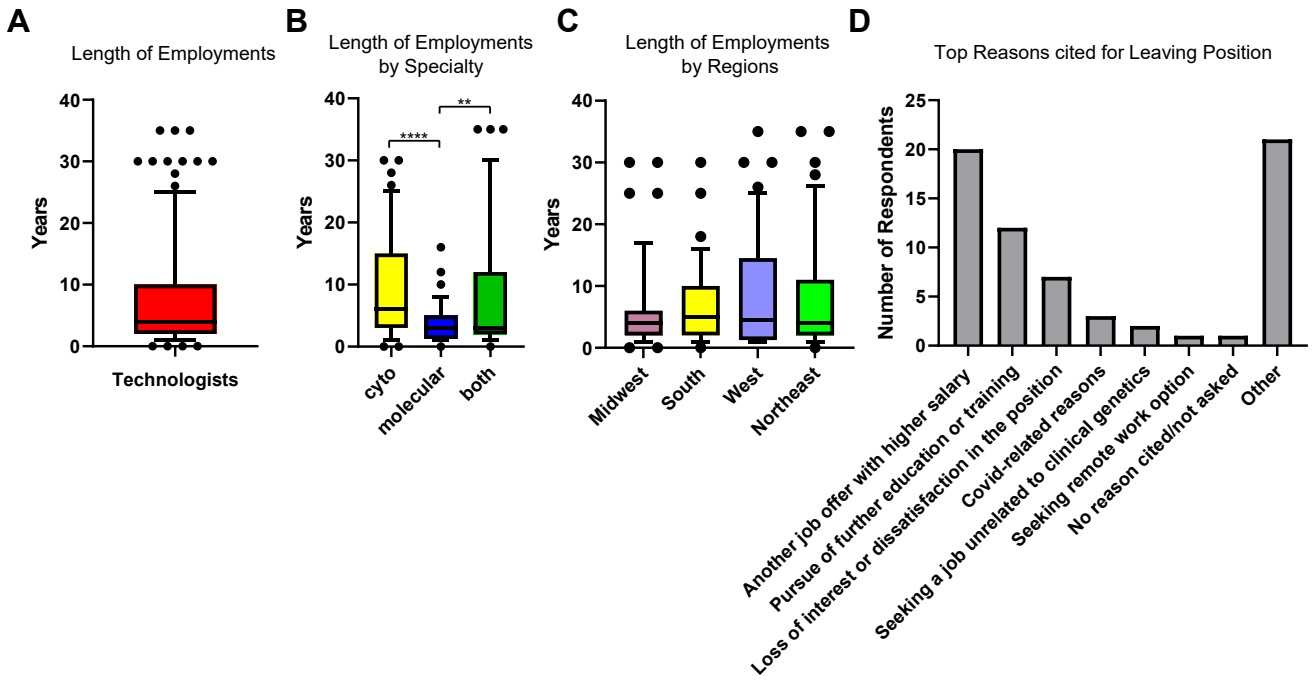

Figure 3 Technologist retention. (A) We surveyed the length of employment of the last three technologists who left the laboratories. Technologists were retained for an average of 7.49 years. (B) When stratified by laboratory specialties, cytogenetic, molecular, and combined technologists were retained for 9.56, 3.68, and 7.67 years, respectively. **** indicates *P*-value < .0001; ** indicates *P*-value < .01, unpaired *t*-test with Welch correction (C) When ranked by region, West had high average technologist retention at 9.02 years, followed by Northeast (8.31 years), South (6.56 years) and Midwest (6.04 years). (D) Reasons technologists cited for leaving the positions are listed in this bar graph. 30% of respondents cited "another job offer with higher salary" as top barrier in technologist retention.

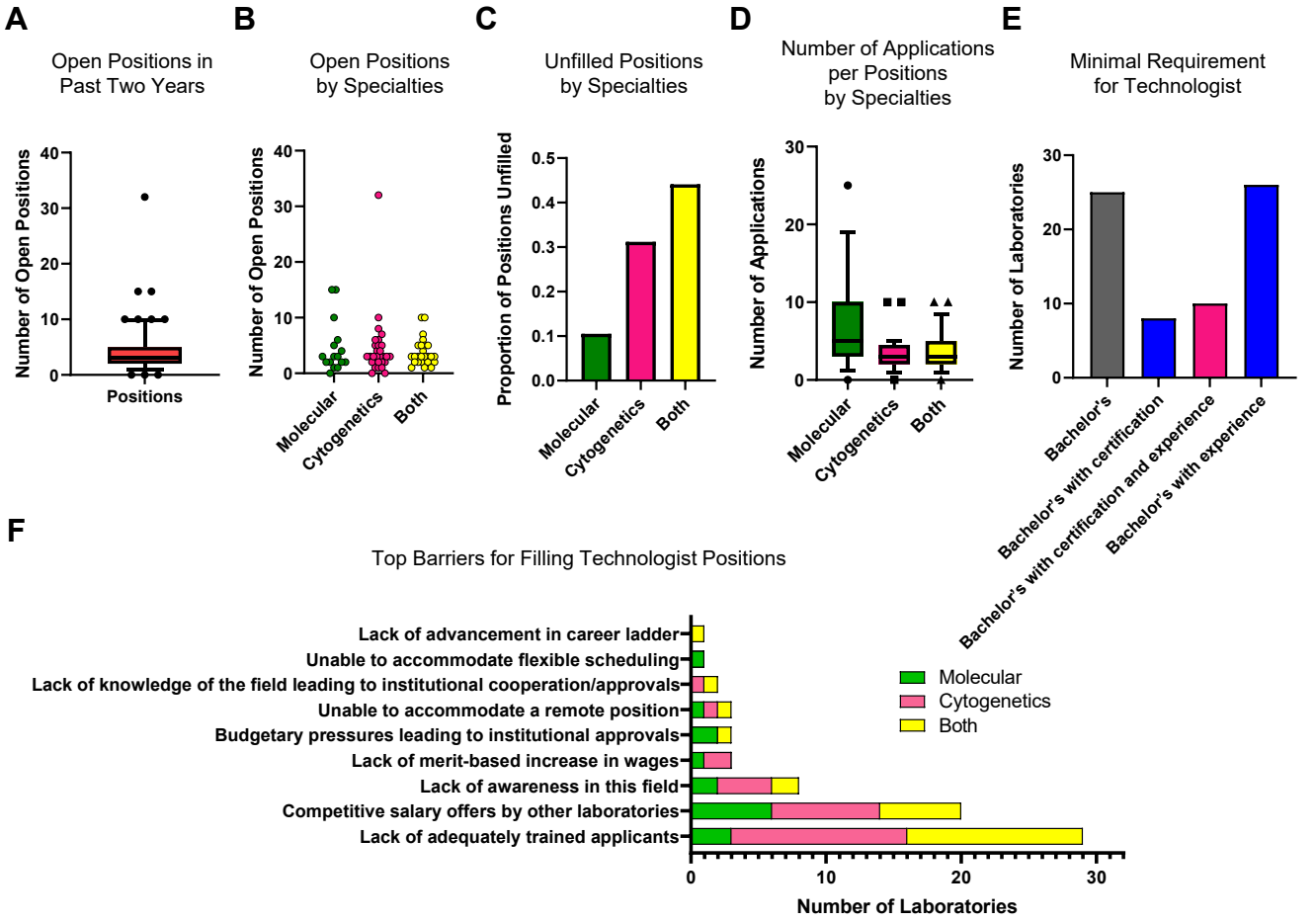

Figure 4 **Technologist recruitment statistics and challenges.** (A) The average number of open positions per laboratory in the last 2 years is 4.2. The whiskers are drawn to the 10th and 90th percentile. Points below and above the whiskers are drawn as individual laboratory responses. (B) When stratified by laboratory specialties, the numbers of open positions did not demonstrate significant differences (*P*-value = .7134, Welch's ANOVA test). Each dot represents an individual laboratory response. (C) The proportion of positions being unfilled are stratified by laboratory specialties. 10.5%, 31%, and 44% were unfiled in molecular, cytogenetic, and combined positions, respectively. (D) Although not statistically significant, it can be appreciated that the average number of applications for each position for molecular (6.73) is higher than those of cytogenetic (3.38) and combined laboratories (3.88) (*P*-value = .1461, Welch's ANOVA test). (E) We surveyed the minimal requirement needed for technologists. 36% required a Bachelor's degree only, whereas 38% required a Bachelor's degree with some relevant laboratory experience. (F) 41% of laboratories cited "lack of adequately trained applicants" as the top barrier in successfully filling a technologist position. *ANOVA*, analysis of variance.

3.88; median = 3) (Figure 4D). Next, we asked about the minimal education requirement for entry-level technologist positions. 36% (25/69) required a Bachelor's degree only, whereas 38% (26/69) required a Bachelor's degree with some relevant laboratory experience (Figure 4E). Lastly, we surveyed the top barrier for successfully filling a technologist position. 41% (29/70) picked "lack of adequately trained applicants," followed by "competitive salary offers by other laboratories" at 29% (20/70), and "lack of awareness in this field" at 11% (8/70). (Figure 4F).

In addition, the survey provided an opportunity for respondents to provide general comments on the current landscape and offer their insights into the staff shortage landscape. Of note, 39 respondents provided comments, which are listed in Supplemental Table 2 (identifiable information was redacted to ensure anonymity). Comments were categorized and summarized in Table 1. Several survey respondents emphasized the low technologist wages relative to the high-complexity scope of work performed. In addition, insufficient recruitment because of poor understanding of cytogenetics, lack of career advancement opportunities, and lack of remote work flexibility were frequently cited by the respondents. One commenter mentioned the lack of automation in the field. In the future, optical cytogenetics may allow more automation; however, the recognition of chromosome analysis will still be necessary. Machine learning may aid in the recognition of abnormalities.

Discussion

Technologists in the United States play an essential role in the clinical genomics laboratory setting because they execute a variety of patient sample processes, such as

Table 1 Categories of comments made by survey respondents

# of respondents	Themes of the comments
6	Low wages for a high complexity workflow
5	Insufficient recruitment to the field combined with poor understanding of Cytogenetics
5	Lack of career advancement for these positions
5	Lack of flexibility related to remote work
4	Strict state licensures (eg, California, New York)
4	Impending retirement of experienced technologists
4	Scarcity of training programs
3	Need to combine cytogenetics and molecular training
1	No good metrics on number of techs/case or number of directors/case
1	Automating Cytogenetics
1	Hiring international workforce

accessioning, tissue culture, nucleic acid extraction, performing various molecular and cytogenetic assays, and data analysis. Since February of 2020, clinical test volumes have spiked, and as a consequence, the demand for personnel resources required to perform testing have also proportionally increased.[10] In order to quantify this increase, a systematic approach of surveying clinical genomics laboratories was urgently needed to define the current landscape of the technologist workforce.

This study provides concrete data aimed to deliver insight into the top barriers in hiring and retaining technologists in both the clinical molecular and cytogenetic laboratories in the United States. Many laboratories stated that the critical lack of adequately trained applicants in this field was a primary concern in filling technologist positions (Figure 4F, Table 1; Supplemental Table 2). This is perhaps not surprising because, as of September 2022, there were only 2 accredited cytogenetics programs and 9 accredited molecular programs (National Accrediting Agency for Clinical Laboratory Sciences) servicing the whole country. This is drastically different from the 244 nationally accredited medical laboratory science programs (MLS) (National Accrediting Agency for Clinical Laboratory Sciences). Although MLS certificate holders may possess knowledge in quality assurance/quality control and test validation relevant to clinical genomics laboratories, they do not have the necessary training in genetics and genomics to perform the necessary high complexity testing without extensive training on the job. Because of the lack of molecular and cytogenetic-trained applicants, laboratories may resort to hiring applicants with MLS credentials only and allow for a longer training period. In addition, as mentioned by respondents, laboratories will have to resort to more automated workflow, especially in cytogenetics. Technological advances in this field, such as optical mapping and artificial intelligence, will be more rapidly implemented to sustain patient care.

Lack of awareness of the field was also cited as a top barrier (Figure 4F). Specifically, directors expressed that students are not aware of cytogenetics and "even hospital administrators think cytogenetics has something to do with cytology." This sentiment is supported by the observation that the number of applicants for cytogenetics positions is only half the number of those applying for molecular positions, and the proportion of unfilled positions in cytogenetics is 3 times of those in molecular (Figure 4C and D). Alternatively, the low number of cytogenetics applicants may also be because of the lack of interest, which is difficult to distinguish from the lack of awareness in this survey. To resolve this, early exposure to clinical genomics testing (especially cytogenetics) may be valuable. Introduction of cytogenetic principles in high school and undergraduate science curricula may motivate students to get educated and subsequently enter the field of genomic testing.

Laboratory directors reported that another job offer with higher salaries was the top reason for technologists leaving their positions (Figure 3D). Directors also expressed that financial compensation offered by industry was higher than academic institutions; thus, it was challenging to hire/retain technologists in the latter (Table 1; Supplemental Table 2). In this survey, we only obtained limited entries from commercial laboratories ($n = 4$); therefore, it is difficult to discern the differences in salary between academic and commercial laboratories. Since the onset of the pandemic, many commercial COVID-19 testing laboratories were launched, drawing away molecular technologists from non-commercial institutions. With the high volume of patient samples and the demand for the laboratory workforce, it is reasonable to assume that commercial entities have a better capacity of offering higher salaries.

It should also be noted that some laboratory directors stated that their experienced cytogenetic technologists had retired or were expected to retire and would be difficult to replace because of the general lack of expertise as described above. This is indirectly reinforced by the data in our study, which demonstrates that cytogenetic technologists were retained for an average of 9.56 years, compared with molecular technologists who were retained for an average of 3.68 years. The loss of experienced technologists, compounded by the lack of adequately trained applicants, further exacerbates the workforce shortage.

To resolve the critical shortage of cytogenetic technologists, it was suggested that technologist programs combine both molecular and cytogenetics training. This combined training in both disciplines is already being implemented by the ABMGG for clinical directors on the PhD (and MD) level in which a diplomate in Laboratory Genetics and Genomics "can direct and interpret both clinical cytogenetic and molecular genetic analyses" (ABMGG). This cross-training in disciplines may help expose the newcomers to the field of cytogenetics, who may only be aware of molecular genetics and infectious disease testing.

Additionally, diversity, equity, and inclusion should be considered as a contributing factor to the workforce in clinical genomics laboratories. It has been reported that diverse leadership and work environment can lead to better recruitment and better job satisfaction.[11,12] Recently, the Human Genetics & Genomics Workforce Survey led by the American Society of Human Genetics published comprehensive analyses on the demographic composition of human genetics and genomics workforce in training programs and the workplace.[13] However, the respondents from this study were mostly master's and doctoral degree holders in the genetic counseling or research environment, and it is difficult to deduce the technologist representation in this study.[13] Future surveys may be conducted to better understand how the diversity of technologist workforce (or lack thereof) may correlate with employment satisfaction and job retention in the clinical genomics laboratories.

It is important to note that there are limitations to this survey. As shown in Figure 1B, the survey respondents are heavily skewed towards academic institutions and community hospitals. This bias makes it difficult to perform a balanced comparison with the commercial laboratories on the differences in salaries and top barriers. Moreover, we circulated this survey using professional connection, the GeneticTestRegistry database as well as the Chromophile email listserv composed primarily of clinical cytogenetics laboratory directors. It is possible that some molecular and cytogenetic laboratories had not been reached. Furthermore, it is critical to emphasize that the findings in this study are specific to the United States and may not be applicable to other countries. Because other countries have different regulations for education and training requirements for clinical testing personnel as well as various socioeconomic policies, they may encounter workforce challenges that are not revealed in this survey.[14,15] Additional studies are needed to generate solutions for workforce shortage in other countries.

Looking ahead, both short-term and long-term strategies are needed in order to address the workforce shortage. To alleviate the immediate needs of technologists, laboratory directors can encourage the cross training in disciplines (eg, molecular technologists also training in cytogenetics). In the short term, directors can give periodic career seminars on clinical genomics in local high schools and universities to increase awareness, whereas in the long term they could be working with universities to establish molecular or cytogenetic avenues within their MLS programs or other undergraduate life science curricula. In the era of precision medicine in which genomic data inform patient diagnosis, prognosis, as well as therapy, it is imperative to acknowledge these issues and strive, collectively as a unified community, to solve these challenges. We consider this survey to be a preliminary step toward in understanding the technologist workforce shortage in the clinical genomics laboratory setting. Periodic surveying of laboratory directors may provide the most updated information on the landscape of the technologist workforce. Hearing directly from the technologists' point of view is critical; thus, surveys specifically targeted to technologists could better assess the motivation and sentiments of job satisfaction from the technologists' point of view. Taken together, the results from this survey would serve as normative data in generating solutions to address future workforce needs.

Data Availability

Redacted data is available upon request. However, no identifiable information will be provided to ensure anonymity.

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The authors have no funding to declare.

Author Information

Conceptualization: Y.A., S.D., R.G.B., and M.L.L.; Data analysis: M.L.L.; Writing-original draft: M.L.L.; Writing-review and editing: Y.A., S.D., R.G.B., and M.L.L.

Ethics Declaration

This study was assessed by the Nationwide Children's Hospital Institutional Review Board, and was determined exempt.

Conflicts of Interest

Y.A. and M.L.L. serve as directors in a clinical laboratory that performs an extensive menu of genetic and genomic testing on a fee-for-service basis. R.G.B. is affiliated with LabCorp. S.D. declares no conflicts of interest.

Additional Information

The online version of this article (https://doi.org/10.1016/j.gimo.2023.100806) contains supplementary material, which is available to authorized users.

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