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ORIGINAL RESEARCH

Impact of Peer-Developed Education on the Clinical Utility of Liquid Biopsy for Advanced Practitioners

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Abstract

Background: Next-generation sequencing (NGS) has expanded the identification of genomic biomarkers to inform treatment selection and is increasingly performed on circulating tumor DNA (ctDNA) via liquid biopsy (LB). It is essential for oncology advanced practitioners (APs) to properly identify patients to undergo biomarker testing and accurately interpret results for patient care. We describe the implementation and impact of a case-based learning (CBL) education program for APs focused on LB-based biomarker testing. **Methods:** A pre/post design was used to evaluate APs participating in interactive CBL sessions focused on LB utility at diagnosis, disease progression, and treatment monitoring. Surveys administered immediately before and after education captured biomarker testing practices, clinical indications for LB, and confidence identifying patients and interpreting results. Statistical analyses included chi-square and paired *t*-tests ($p < .05$). **Results:** A total of 106 participants from more than 15 institutions completed paired surveys. Baseline practices for biomarker testing most commonly included tissue-first with reflex to LB or concurrent testing. After education, 50% of APs reported they would consider LB use for expanded clinical indications. All cohorts demonstrated statistically significant improvements in confidence identifying appropriate patients and interpreting or explaining LB-based comprehensive genomic profiling results ($p < .01$), with the greatest gains among APs with 0 to 3 years of experience. Nearly all participants (97%) felt confident identifying patients eligible for liquid biopsy post-education. **Conclusion:** Peer-developed CBL significantly improved AP confidence and understanding of LB-based biomarker testing. Integrating structured, AP-led education into oncology training may enhance precision oncology practice and support guideline-aligned patient care.

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Advanced practitioners (APs), including nurse practitioners, physician assistants, clinical nurse specialists, and clinical pharmacists, comprise a significant portion of the oncology workforce, with more than 80% of oncology practices in the United States employing APs (Braun-Inglis et al., 2022; Vogel, 2016). Despite their advanced clinical training, many APs enter practice without formal oncology-specific education (Vogel, 2010). This educational gap becomes particularly challenging as oncology rapidly advances toward personalized medicine, highlighting the need for AP proficiency in biomarker testing and molecular diagnostics (Bruinooge et al., 2018; Moore & Guinigundo, 2023b, 2023c).

In recent years, rapid advances in next-generation sequencing (NGS) have revolutionized the landscape of biomarker testing. Next-generation sequencing enables the simultaneous evaluation of numerous genes, thereby expediting and expanding the identification of potentially targetable mutations across a variety of solid tumors (Guan et al., 2012; Moore & Guinigundo, 2023c, 2023a). Alongside tissue-based assays, liquid biopsy has emerged as a minimally invasive and practical complement for real-time molecular profiling. Liquid biopsy assesses circulating tumor DNA (ctDNA) shed in plasma and has unique advantages and limitations when compared to tissue-based profiling. By capturing ctDNA from the primary tumor and metastatic sites simultaneously, liquid biopsy may help overcome challenges posed by spatial and temporal heterogeneity while offering a minimally invasive approach to more comprehensively characterize the tumor's genomic profile (García-Pardo et al., 2022). Numerous cancer guidelines have incorporated liquid biopsy to guide treatment decisions, particularly when results are needed quickly, tissue samples are insufficient or biopsy infeasible, or when acquired resistance to treatment is suspected (García-Pardo et al., 2022; Moore & Guinigundo, 2023c). However, sensitivity may be reduced in the setting of low tumor burden or biologically low-shedding disease (García-Pardo et al., 2022).

Despite the growing importance of biomarker testing, many APs receive limited formal training in genomics and may lack confidence knowing when to order biomarker testing and how to accurately interpret and explain results to patients (Stewart et al., 2024; Walker et al., 2024). Although both physicians and APs may report gaps in preparedness for the advances of personalized medicine, oncologists typically receive more foundational education in cell and molecular biology and complete structured oncology fellowships (Kudron et al., 2023). In contrast, APs complete rigorous graduate education and certification within population-focused training programs that may not consistently include oncology-specific content or exposure. As a result, oncology-related competencies are often developed in practice and influenced by available institutional resources and physician collaboration (Vogel, 2010).

While on-the-job experience can build some expertise, APs may additionally benefit from organized educational interventions that focus on essential concepts of biomarker testing (Faiman, 2024; Moore & Guinigundo, 2023b; Stewart et al., 2024). When APs possess a deeper understanding of biomarker testing, they can expedite appropriate referrals, more confidently recommend targeted therapies, and better advocate for the integration of genomic insights into multidisciplinary care (Moore & Guinigundo, 2023b). Additionally, recent policy changes such as the 21st Century Cures Act mandate immediate patient access to test results, placing increased pressure on APs to accurately and clearly discuss genomic findings promptly upon patient awareness of results (Faiman, 2024).

As APs navigate increasingly complex oncology care management, it is essential they understand patient eligibility for biomarker testing and the accurate interpretation of newer technologies such as liquid biopsy (Moore & Guinigundo, 2023b). Given its distinct advantages and limitations, APs must be equipped to recognize when liquid biopsy is appropriate and how to interpret results that may influence patient care. Here, we describe the implementation and impact of a case-based learning (CBL) education program for APs focused on the utility of liquid biopsy–based biomarker testing.

METHODS

Educational Program

A team of oncology APs within the Medical Affairs organization of a precision oncology company

developed CBL content to educate APs in clinical practice about the importance of biomarker testing and the utility of liquid biopsy for advanced-stage cancer patients. The educational content focused on the following principles:

- Introduction to ctDNA and liquid biopsy, including methodological strengths and limitations
- Interpretation of liquid biopsy results, emphasizing concepts such as cell-free DNA (cfDNA), variant allele fraction (VAF), and significance of genomic alterations such as single nucleotide variants (SNVs), insertions/deletions (indels), etc.
- Clinical scenarios illustrating liquid biopsy's utility at diagnosis, disease progression, and therapy monitoring.
- Strategies for clear and effective communication of complex genomic results to patients.

Educational content was delivered over 11 sessions via interactive case presentations facilitated live (both in-person and virtually). A pre- and post-test assessment was used to evaluate the effectiveness of a peer-developed education aimed at enhancing APs' proficiency with liquid biopsy-based biomarker testing. While experiences are presented here in study format, this effort was initiated to improve health-care operations related to clinical education and/or refine educational content provided to APs.

Education Setting and Attendees

Education session attendees, including oncology APs, were invited to complete a pre- and post-test assessment for continued improvement of educational content. Participants were categorized based on years of oncology experience (0–3, 4–10, 11+) and practice setting (academic, community) to determine variability in educational impact and identify unique opportunities for refinement of educational content and/or improvements in health-care operations for clinical education.

Data Collection

Participants completed a structured survey immediately before and after the educational sessions electronically or in paper format, depending on the session modality (in person or virtual). The survey evaluated: (1) baseline paradigms used for obtaining biomarker testing (e.g., tissue-first, liquid biopsy-first, concurrent approaches); and (2) clinical indications and timing for ordering liquid biopsy (initial diagnosis, disease progression, treatment response monitoring). The survey also assessed confidence levels regarding the identification of appropriate patients for liquid biopsy, interpreting genomic findings, and communicating these findings clearly to patients. Additionally, post-education assessments captured intended practice changes and participant feedback on the utility of the educational materials. The full survey instrument is provided in Appendix A.

Statistical Analysis

Paired *t*-tests and chi-square analyses were used to evaluate pre- and post-education differences in survey responses, with a significance threshold set at $p < .05$. Descriptive statistics summarized participant demographics, clinical settings, and baseline biomarker testing practices. Analyses accounted for potential confounding variables, including practice setting and oncology experience level.

RESULTS

Attendee Demographics

A total of 105 oncology APs and one nurse navigator from over 15 oncology institutions across the US participated in the educational program and completed paired surveys. Most reported working in a community setting (80/106, 75%, Figure 1A) and having 10 years or less experience as oncology APs (81/106, 76%, Figure 1B). For attendees who responded "other" for their practice setting ($n = 7$), responses included those working at a teaching hospital ($n = 1$), inpatient setting ($n = 2$), outpatient office ($n = 1$), oncology clinic ($n = 1$) and not applicable or no answer ($n = 2$). There was no significant difference in distribution of practice settings (academic/community) across years of experience ($p = .48$, Figure 1C).

Baseline Reported Clinical Paradigms for Obtaining Biomarker Testing in Newly Diagnosed Advanced NSCLC (aNSCLC)

The most common clinical paradigms used for biomarker testing were tissue-first with reflex to liquid biopsy if tissue quantity was not sufficient (36%) and concurrent testing with tissue and liquid (35%; Figure 2A). Only oncology APs in community

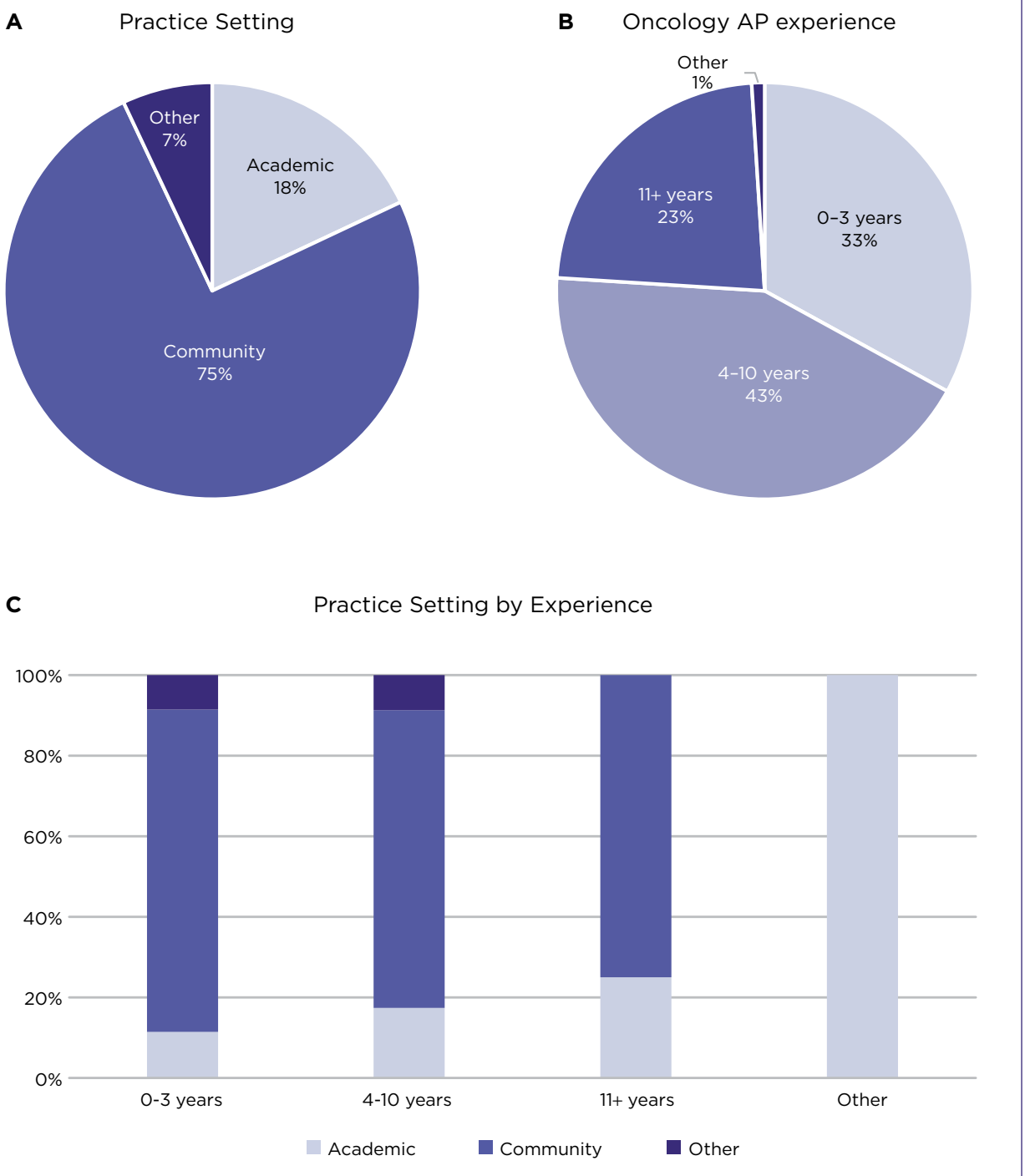
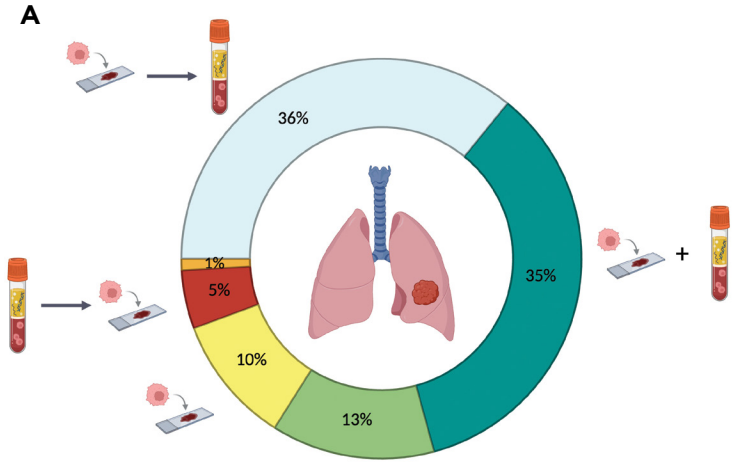
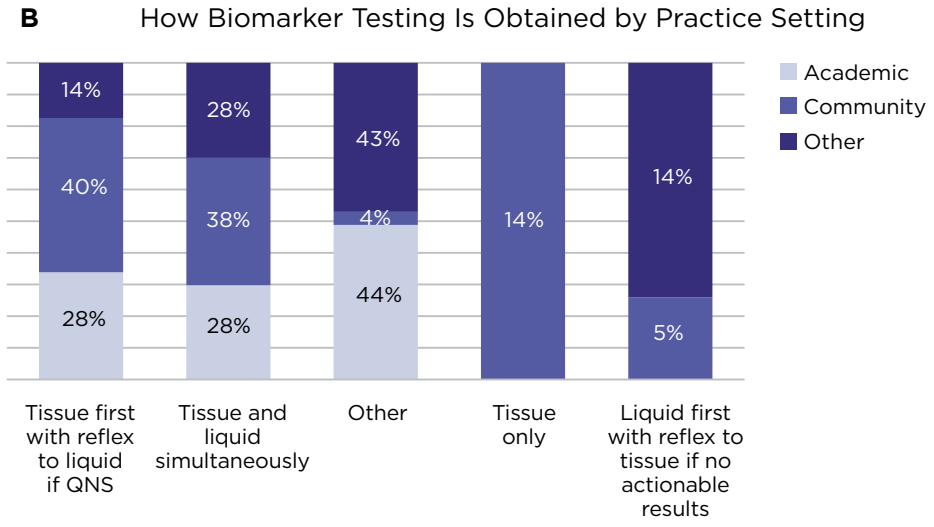


Figure 1. Demographics of educational program attendees. (A) Practice setting, (B) years of oncology AP experience, and (C) practice setting distribution within experience groups.





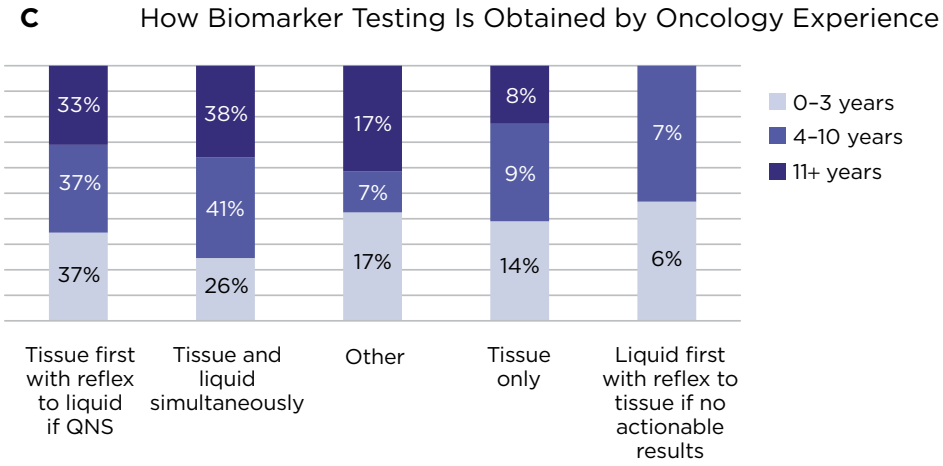


Figure 2. How APs report obtaining biomarker testing in newly diagnosed aNSCLC. Reported clinical paradigms of how biomarker testing is obtained in the (A) overall cohort, (B) by practice setting, and (C) by years of oncology experience. QNS = quantity not sufficient. Figure 2A created in BioRender. Welch, L. (2026) https://BioRender.com/jb1h4jy.

settings reported using tissue-only or liquid-first paradigms to offer biomarker testing (Figure 2B). No participant with 11+ years of oncology AP experience reported using liquid-first paradigms; all relied upon tissue within their biomarker testing paradigms (Figure 2C). Notably, 13% of participants reported using "other" paradigms to offer biomarker testing, including tumor-type specific approaches, team-based ordering, or paradigms related to inpatient/outpatient status (Figure 2A).

Clinical Settings Liquid Biopsy Considered Across Cancer Types: Pre- and Post-Education Results

A total of 105 APs provided information about the clinical indications for which they order biomarker testing via liquid biopsy. Prior to education, most APs reported using liquid biopsy at the time of new diagnosis (n = 64) or clinical progression (n = 78), either alone or in combination with other settings (Table 1). After education, 28% (29/105) reported they would consider liquid biopsy for the same indications, while 50% (53/105) reported they would consider liquid biopsy for expanded indications.

Post-Education Changes Among APs Who Originally Used Liquid Biopsy at New Diagnosis Only

Among participants who reported using liquid biopsy at new diagnosis only (n = 12), 83% (10/12) indicated after the education that they would also consider using liquid biopsy at clinical progression and/or treatment monitoring (Figure 3A).

Post-Education Changes Among APs Who Originally Used Liquid Biopsy at Clinical Progression Only

Of those who reported considering use of liquid biopsy at clinical progression only (n = 26), 69% (18/26) indicated they would expand use to the new diagnosis setting post-education (Figure 3B).

Post-Education Changes Among APs Who Used Liquid Biopsy in Newly Diagnosed and Clinical Progression at Baseline

Advanced practitioners who used liquid biopsy at new diagnosis and clinical progression before education (n = 40) showed additional broadening of intended use: 57.5% (23/40) reported they would expand use to the treatment monitoring setting (Figure 3C), and 37.5% (15/40) retained their original selections, but nonetheless demonstrated a significant increase in confidence regarding use of liquid biopsy in these settings (mean score 3.6 to 4.3, $p < .01$).

Post-Education Changes Among APs With no Identified Pre-Education Use for Liquid Biopsy

Among APs who initially reported no use or no applicable clinical setting for liquid biopsy (n = 4), 75% (3/4) indicated after education they would now consider using liquid biopsy at new diagnosis and/or clinical progression. The remaining attendee selected "other", noting this choice was influenced by a specialization in radiation oncology (Figure 3D).

AP Confidence Identifying Appropriate Patients for Biomarker Testing

All 106 educational program attendees provided responses regarding their confidence to appropriately identify patients for liquid biopsy–based biomarker testing and interpreting and explaining results to patients before and after education. When

Table 1. Reported Clinical Indications for Liquid Biopsy at Baseline (N = 105)

Clinical indication	Percentage (no.)
Newly diagnosed and clinical progression	38% (40)
Clinical progression	25% (26)
Newly diagnosed	11% (12)
Newly diagnosed, clinical progression, and monitoring for treatment response	11% (12)
Other	10% (10)
Liquid biopsy is not utilized in my practice	4% (4)
Monitoring for treatment response	1% (1)

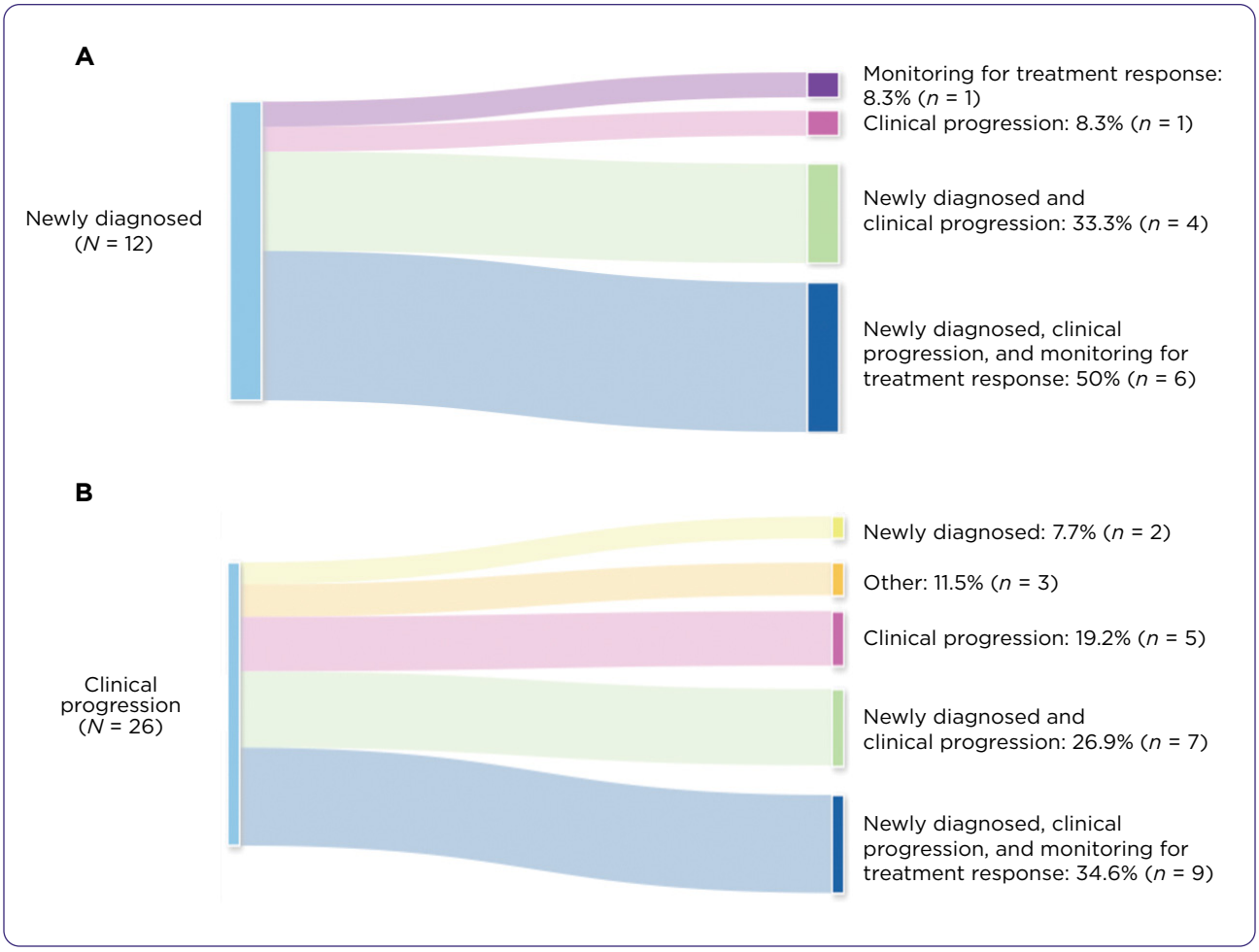


Figure 3. Clinical indications of liquid biopsy reported in pre- and post-survey results. Sankey plots depicting post-education changes of considered clinical indications for liquid biopsy utility among (A) those who selected newly diagnosed only at baseline, (B) clinical progression only at baseline, (C) newly diagnosed and clinical progression at baseline, and (D) no use of liquid biopsy at baseline.

asked to rank their confidence on a scale of 1 (low) to 5 (high) of knowing when to order biomarker testing via liquid biopsy, most attendees (68/106, 64%) selected moderate (3) or moderately high (4) confidence at baseline. After education, 82% (87/106) ranked their confidence as moderately high (4) or high (5). There was more than a threefold increase of attendees reporting high confidence post-education (n = 10 at baseline, n = 35 post-education; Figure 4). All cohorts, across years of experience and practice setting, experienced a statistically significant increase in confidence to identify patients appropriate for biomarker testing with liquid biopsy post-education compared to pre-education ($p < .01$; Table 2). The greatest numeric increase in confidence was observed for APs with 0 to 3 years' experience (+1.17). There was no difference in increase in confidence across settings (p = 1.0), with similar numeric increases in confidence for academic and community practitioners (+1.0 and +0.92, respectively).

AP Confidence Interpreting and Explaining Biomarker Results to Patients

Most attendees (65/106, 61%) reported moderate (3) or moderately high (4) confidence interpreting and explaining biomarker testing results to patients at baseline. After education, the number of attendees reporting high confidence (5) in interpreting and explaining results to patients more than doubled (n = 13 at baseline, n = 30 post education; Figure 5). Compared to pre-education ratings, all groups

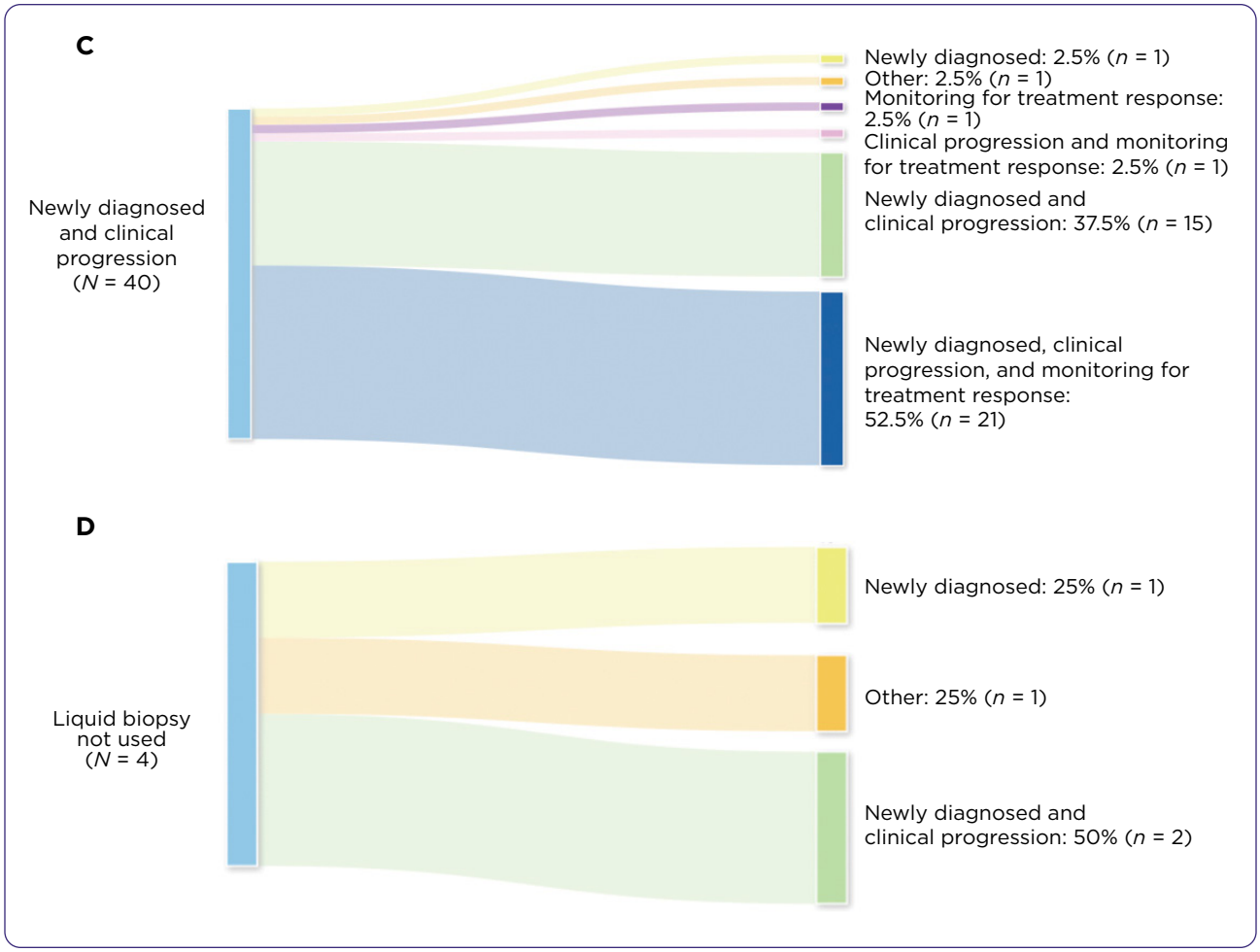


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across years of experience and practice setting experienced a statistically significant increase in confidence post-education ($p < .01$; Table 3). Advanced practitioners with 0 to 3 years of experience had the greatest numeric increase in confidence (+1.11) compared to those with 4 to 10 (+0.53) or 11+ years' experience (+0.67), although this was not statistically significant between groups ($p = 1.0$). Advanced practitioners in academic settings had a greater numeric increase in confidence (+0.89) compared to APs in the community setting (+0.66), although this was also not statistically significant ($p = 1.0$).

Potential Clinical Impact of AP Education

Following the education program, nearly all attendees (97%, 103/106) reported feeling confident in identifying patients appropriate for biomarker testing with liquid biopsy. Furthermore, 99% (105/106) indicated that the education would inform their clinical practice and that they would recommend the program to other APs.

CONCLUSIONS

The pre- and post-survey results demonstrate that a peer-developed CBL program significantly improved APs' confidence to identify appropriate patients for liquid biopsy and interpret and communicate test results. These improvements were observed consistently across clinical settings and years of oncology experience. In alignment with the educational program objectives, the findings affirm the value of structured educational interventions

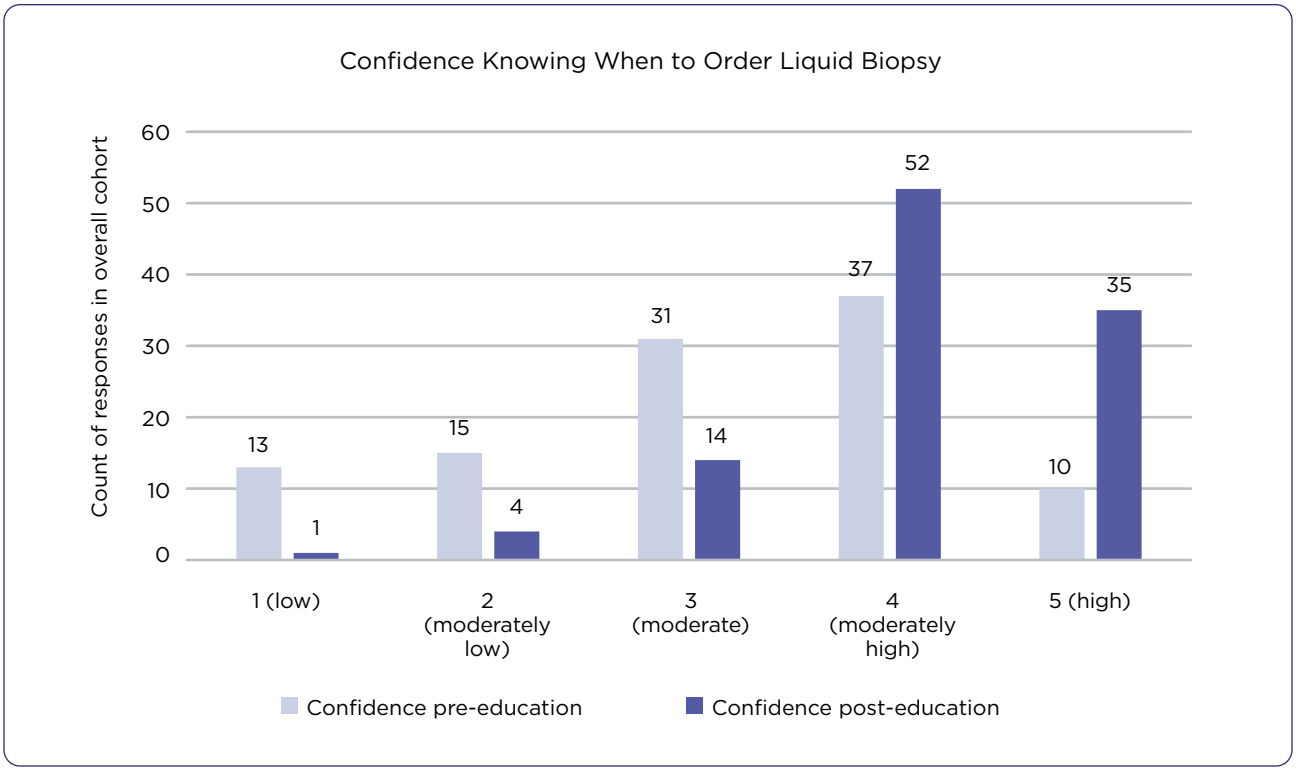


Figure 4. Reported confidence of knowing when it may be appropriate to order biomarker testing with liquid biopsy before and after education.

to address persistent knowledge gaps in precision oncology, particularly as APs increasingly serve as frontline providers in cancer care.

This work adds to the growing literature supporting targeted educational programs that equip APs to adopt and apply evolving genomic technologies (Goldgar et al., 2016; Moore & Guinigundo, 2023b, 2023a). By emphasizing real-world clinical scenarios and incorporating fundamental principles of ctDNA and genomics, the CBL program demonstrated strong applicability and was widely recommended by participants for use in clinical practice. These findings suggest that similar programs could be scaled and adapted across institutions to support consistent, guideline-aligned integration of biomarker testing and enhance multidisciplinary care.

This CBL educational program has several limitations. While the inclusion of a diverse group of APs from both academic and community

Table 2. Change in Reported Confidence of Knowing When to Order Biomarker Testing With Liquid Biopsy by Years of Oncology Experience and Practice Setting

Years of experience	Pre-education ranking (mean)	Post-education ranking (mean)	*p* value
0–3	2.77	3.94	$p < .01$
4–10	3.43	4.26	$p < .01$
11+	3.26	4.0	$p < .01$
Practice setting	**Pre-education ranking (mean)**	**Post-education ranking (mean)**	***p* value**
Academic	3.26	4.26	$p < .01$
Community	3.16	4.08	$p < .01$

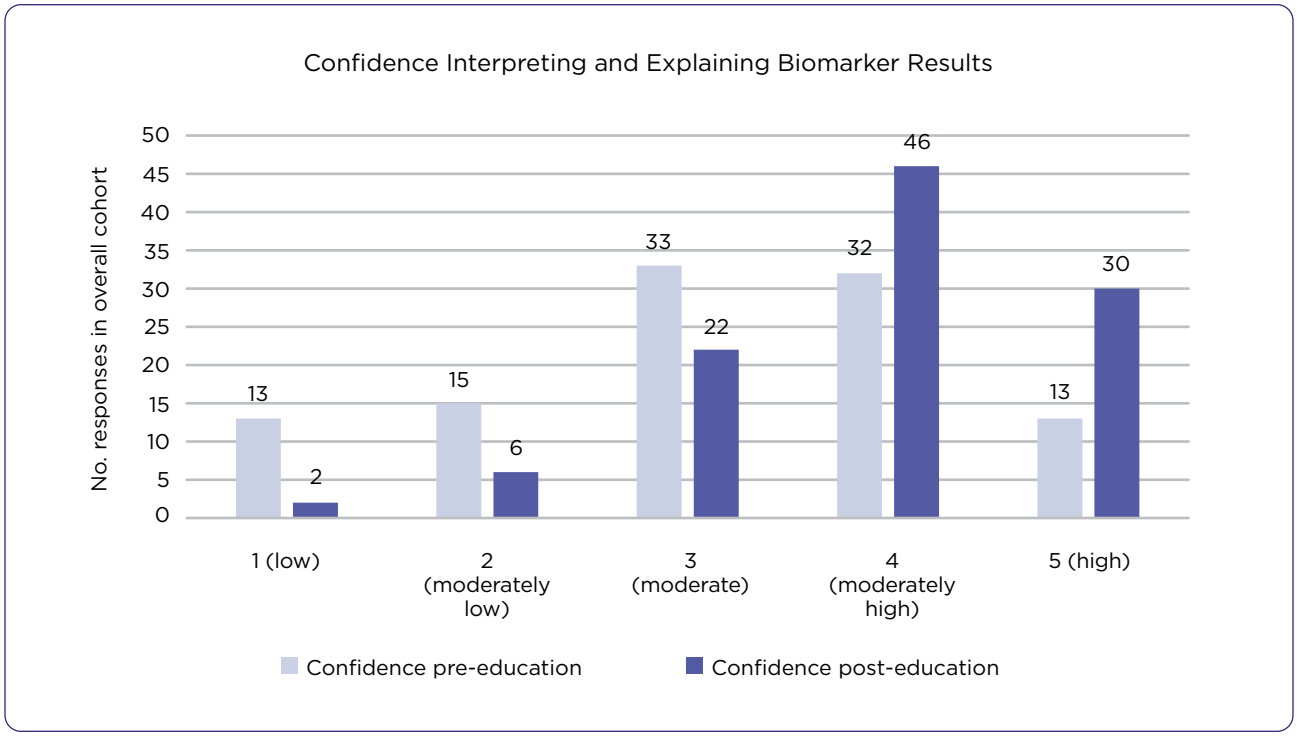


Figure 5. Reported confidence of interpreting and explaining biomarker testing results to patients before and after education.

practices supports broader relevance, the relatively small sample size limits generalizability. A larger cohort may help clarify numerical trends that did not reach statistical significance, such as differences in confidence gains by years of experience and/or practice setting. Attendees elected to participate in an educational program, either in-person or virtually, which may present bias and further limit generalizability. The absence of long-term follow-up limits conclusions regarding knowledge retention and sustained changes in clinical practice. Additionally, survey assessments are subject to response and self-selection bias and do not allow for in-depth exploration of participant perspectives. The impact of this educational program on patient outcomes was not assessed. Additionally, although efforts were made to provide balanced education, the development of the educational content by a precision oncology company may introduce potential bias, which should be considered when interpreting the findings.

The results from this peer-developed CBL education highlight the need for future educational programs to evaluate long-term outcomes and the

Table 3. Change in Reported Confidence Interpreting and Explaining Biomarker Testing Results by Years of Oncology Experience and Practice Setting

Years of experience	Pre-education ranking (mean)	Post-education ranking (mean)	*p* value
0–3	2.66	3.77	$p < .01$
4–10	3.54	4.07	$p < .01$
11+	3.12	3.79	$p < .01$
Practice setting	**Pre-education ranking (mean)**	**Post-education ranking (mean)**	***p* value**
Academic	3.32	4.21	$p < .01$
Community	3.20	3.86	$p < .01$

effect of such educational interventions on clinical decision-making, operations, and patient care. As precision oncology continues to evolve, ongoing investment in AP education will be essential to ensure consistent application and accurate interpretation of biomarker testing in clinical practice. By strengthening APs' ability to identify eligible patients, interpret complex molecular results, and communicate findings confidently, structured education has the potential to support more timely and appropriate treatment selection, ultimately improving outcomes across the cancer care continuum. ●

Disclosure

Ms. Welch, Ms. Hankins, Dr. Graham-Adderton, Dr. Suk, Mr. Ford, Ms. Persinger, Ms. Harvell, Ms. O'Neal, Dr. Novruzov, and Ms. Bucheit are employees of Guardant Health and hold Guardant Health stock. Ms. Anderson has no conflicts of interest to disclose.

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Appendix A. Pre- and Post-Education Survey Instrument
Pre-Education Survey
Participant characteristics
1. How long have you worked as an oncology advanced practitioner (AP)?
A. 0–3 years
B. 4–10 years
C. ≥ 11 years
2. What setting most accurately describes your clinical practice?
A. Community
B. Academic
C. Other (please specify)
Biomarker testing practices
3. What is the best description of how you most often obtain comprehensive genomic profiling (CGP) for newly diagnosed non-small cell lung cancer (NSCLC)?
A. Tissue only
B. Tissue and liquid simultaneously
C. Tissue first with reflex to liquid if quantity not sufficient
D. Liquid first with reflex to tissue if no actionable results
E. Other (please specify)
4. In which clinical settings do you order liquid biopsy CGP? (Select all that apply)
A. Newly diagnosed
B. Clinical progression
C. Monitoring for treatment response
D. Liquid biopsy is not utilized in my practice
E. Other (please specify)
Confidence assessment
5. Rank your confidence in knowing when it may be appropriate to order genomic testing via liquid biopsy:
1 (Low) – 5 (High)
6. Rank your confidence in interpreting and explaining genomic results to patients:
1 (Low) – 5 (High)

Appendix A. Pre- and Post-Education Survey Instrument (cont.)
Post-Education Survey
7. Did you learn something new that will impact your clinical practice?
A. Yes
B. No
C. Uncertain
8. Following this session, do you feel you can identify patients who may benefit from CGP via liquid biopsy?
A. Yes
B. No
C. Uncertain
9. In which clinical settings are you most likely to order liquid biopsy now? (Select all that apply)
A. Newly diagnosed
B. Clinical progression
C. Monitoring for treatment response
D. I do not plan to use liquid biopsy
E. Other (please specify)
Confidence assessment (post-education)
10. Rank your confidence in knowing when it may be appropriate to order genomic testing via liquid biopsy:
1 (Low) – 5 (High)
11. Rank your confidence in interpreting and explaining genomic results to patients:
1 (Low) – 5 (High)
Program feedback
12. Would you recommend this educational program to other APPs?
A. Yes
B. No
C. Uncertain
13. Please provide any additional comments or feedback:
Free text response