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PERCEPTIONS OF MOLECULAR BIOMARKER TESTING IN CANCER DIAGNOSIS AMONG ONCOLOGY CLINICIANS

Original Research

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ABSTRACT

Background: Molecular biomarker testing has become a cornerstone of precision oncology, guiding targeted therapy and improving diagnostic accuracy. However, its integration into routine cancer care, particularly in low- and middle-income countries, remains suboptimal due to multifactorial challenges.

Objective: To explore the experiences, attitudes, and perceived barriers faced by oncology clinicians in implementing molecular biomarker testing in routine cancer care in Lahore, Pakistan.

Methods: A qualitative descriptive study was conducted over eight months in Lahore, utilizing purposive sampling to recruit 23 oncology clinicians from public and private tertiary care hospitals. Semi-structured, in-depth interviews were audio-recorded, transcribed, and analyzed using Braun and Clarke's thematic analysis framework. Data saturation was achieved and NVivo software supported systematic coding.

Results: Five major themes emerged: clinical relevance and awareness, operational and logistical challenges, educational and training gaps, ethical and emotional dilemmas, and systemic and policy-driven barriers. Clinicians reported variability in biomarker knowledge, difficulties in interpreting results, infrastructure limitations, and lack of standardized protocols. Emotional strain in discussing ambiguous or unactionable results, and disparities in patient access due to financial constraints, were also prominent. Participants emphasized the need for clearer guidelines, institutional support, and continued medical education.

Conclusion: The study highlights the complex landscape surrounding biomarker testing adoption in oncology practice within a resource-limited setting. Addressing the identified barriers through systemic reform, clinician support, and targeted education can enhance the practical uptake of precision diagnostics, ultimately improving cancer care delivery in similar contexts.

Keywords: Attitude of Health Personnel, Biomarkers, Cancer Diagnosis, Health Services Accessibility, Molecular Diagnostic Techniques, Oncology, Pakistan, Precision Medicine, Qualitative Research, Workflow.

INTRODUCTION

Molecular biomarker testing has emerged as a transformative element in cancer diagnosis and treatment, offering insights that can personalize and optimize therapeutic strategies. By identifying genetic mutations, protein expressions, and other molecular signatures unique to a patient's tumor, clinicians can make more informed decisions about targeted therapies, prognosis, and clinical trial eligibility (1). In recent years, advances in genomic technologies and precision medicine have expanded the potential of biomarker-guided cancer care, positioning it as a cornerstone of modern oncology (2). Despite these promising developments, the integration of molecular biomarker testing into routine clinical practice remains inconsistent. Variability in access, knowledge gaps among providers, logistical constraints, and systemic disparities continue to hinder its widespread adoption (3,4). The shift from traditional histopathological diagnosis to biomarker-driven precision oncology represents not just a technical transition but also a cultural and operational one. Clinicians are at the heart of this shift, playing a pivotal role in test selection, result interpretation, and patient communication (5). Their engagement, therefore, becomes essential in the successful implementation of molecular testing strategies. However, while studies have examined patient perspectives and policy-level challenges, fewer have explored the nuanced experiences and viewpoints of oncology clinicians who serve as gatekeepers of these advanced diagnostic tools (6,7). A deep understanding of their perspectives is necessary to identify what facilitates or impedes the routine use of biomarker tests in everyday clinical workflows.

Previous research highlights that even in well-resourced settings, many oncologists feel underprepared to navigate the rapidly evolving landscape of molecular diagnostics. For example, some report difficulties in interpreting complex genomic reports, uncertainty regarding the clinical utility of certain biomarkers, and time constraints during consultations that prevent thorough discussions with patients (8). In addition, system-level factors such as test availability, insurance coverage, and institutional guidelines further shape clinicians' ability to use molecular tools effectively. These multifaceted challenges suggest that improving uptake requires more than technological advancements—it demands attention to the lived realities and attitudes of healthcare providers (9). Moreover, the growing volume of available biomarker tests can be both a blessing and a burden. As the number of clinically actionable mutations increases, so too does the complexity of clinical decision-making. This adds pressure on clinicians to stay current with evolving guidelines and emerging evidence (10,11). Training and continuing education are often recommended as solutions, but their impact depends heavily on how they align with clinicians' actual needs and practice environments. Understanding the specific barriers clinicians perceive—whether related to knowledge, infrastructure, or systemic inequities—is crucial for designing interventions that are both practical and scalable (12).

Additionally, there are emotional and ethical dimensions to consider. Clinicians often wrestle with how to convey biomarker findings to patients, especially when results are ambiguous or when targeted therapies are unavailable due to cost or access limitations. These dilemmas can create frustration, moral distress, and even contribute to decision fatigue (13). The clinician's perspective, therefore, is not merely technical—it is deeply human and influenced by a range of cognitive, emotional, and contextual factors. Addressing these dimensions is vital if the healthcare system is to fully leverage the promise of molecular diagnostics. To date, much of the literature surrounding biomarker testing focuses on technical performance, clinical utility, or patient outcomes, with limited qualitative exploration of the provider's experience. This leaves a critical gap in understanding how clinicians perceive and navigate the implementation of molecular testing in real-world oncology settings. By giving voice to their insights, concerns, and suggestions, research can uncover practical levers for improving integration into standard care. It is through these perspectives that policy, education, and infrastructure can be aligned more effectively with frontline realities. In response to this gap, the present study aims to explore oncology clinicians' experiences, attitudes, and perceived barriers related to molecular biomarker testing in cancer diagnosis. The objective is to provide a nuanced understanding of the facilitators and obstacles to incorporating molecular diagnostics into routine care, from the viewpoint of those directly responsible for its application.

METHODS

This qualitative study was conducted over an eight-month period in the Lahore region of Pakistan, aiming to explore the lived experiences, attitudes, and perceived barriers faced by oncology clinicians in implementing molecular biomarker testing in routine cancer care. The study employed a descriptive qualitative design, which is particularly suited to gaining rich, contextual insights into

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healthcare professionals' perspectives within their real-world clinical environments. Through this methodology, the research sought to understand not only what clinicians experience but also how they interpret and navigate the practical and emotional complexities of integrating molecular diagnostics into cancer care. Participants were recruited using purposive sampling to ensure a diverse and information-rich representation of oncology clinicians. The sample included medical oncologists, radiation oncologists, hematologists, and oncology fellows practicing at both public and private tertiary care hospitals within Lahore. Inclusion criteria specified that participants must have at least two years of experience in oncology practice and be actively involved in cancer diagnosis or treatment decisions where molecular biomarker testing might be applicable (14,15). Clinicians who were not directly involved in treatment planning, such as pathologists or laboratory personnel, were excluded to maintain a focused exploration of clinical decision-making processes. Based on the principle of data saturation and existing literature on qualitative sample adequacy, a total of 20 participants were initially targeted. However, interviews were continued until thematic redundancy was achieved at 23 participants, at which point no new concepts were emerging. This approach ensured comprehensive coverage of perspectives while adhering to rigorous qualitative sampling standards.

Data collection was carried out through semi-structured, in-depth interviews conducted in person at participants' workplaces or in a private setting, based on their preference. Each interview lasted approximately 45 to 60 minutes and was guided by an interview protocol developed by the research team. The protocol included open-ended questions designed to elicit clinicians' experiences with ordering, interpreting, and discussing molecular tests; perceived barriers and facilitators to implementation; and recommendations for improving integration into clinical practice. Probes and follow-up questions were used to deepen the conversation and clarify ambiguities. Interviews were conducted in English, Urdu, or a mix of both languages depending on participant comfort, and were audio-recorded with informed consent. All interviews were transcribed verbatim, and Urdu responses were translated into English while preserving contextual meaning. Transcripts were checked against audio recordings to ensure accuracy. Data analysis was performed using thematic content analysis, following Braun and Clarke's six-step framework. This involved familiarization with the data, generation of initial codes, searching for and reviewing themes, defining and naming themes, and producing the final report. NVivo software (version 12) was used to facilitate the organization, coding, and retrieval of data, ensuring a systematic and transparent analytic process. To enhance the trustworthiness of the findings, multiple strategies were employed. Triangulation of data sources was achieved by recruiting clinicians from various institutional settings.

Investigator triangulation was ensured by involving more than one researcher in coding and theme development, with discrepancies resolved through discussion until consensus was reached. Member checking was also conducted by sharing preliminary findings with selected participants to confirm accuracy and resonance with their experiences. Reflexivity was maintained throughout the research process to minimize researcher bias, with detailed field notes recorded after each interview to capture contextual observations and reflective insights. Ethical approval for the study was obtained from the Institutional Review Board (IRB) of the relevant institute. All participants were provided with an information sheet detailing the purpose, voluntary nature, and confidentiality safeguards of the study. Written informed consent was obtained prior to participation, and participants were assured of their right to withdraw at any stage without consequences. Data were anonymized and stored securely, accessible only to the core research team. The primary outcome measure in this study was the identification of recurrent themes representing clinicians' perceived barriers, attitudes, and contextual experiences related to the use of molecular biomarker testing in cancer care. These thematic outcomes were then used to construct a conceptual understanding of the systemic, educational, and infrastructural factors influencing the uptake of molecular diagnostics in the local oncology landscape.

RESULTS

The data analysis revealed five major themes and multiple interconnected subthemes, illustrating the complex landscape oncology clinicians navigate when integrating molecular biomarker testing into cancer care in Lahore. These themes reflect a range of cognitive, institutional, emotional, and systemic factors that influence clinical practice. A prominent theme was *Clinical Relevance and Awareness*. Many participants expressed variable levels of understanding regarding the clinical utility of biomarker testing. While some clinicians confidently used molecular profiling to guide therapeutic choices, others hesitated due to uncertainty about its relevance to specific cancer subtypes. This variability was often influenced by access to current literature or institutional exposure. One participant remarked, *"Sometimes I don't know whether the test will even change the management plan, so I skip it."* Additionally, a lack of familiarity with emerging biomarkers—especially those not yet part of routine protocols—created hesitation among clinicians who feared misinterpretation.

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Operational and Logistical Challenges also emerged strongly. Limited laboratory infrastructure, long turnaround times for test results, and inconsistent access to advanced testing facilities were frequently mentioned. Cost constraints were particularly emphasized, with clinicians citing affordability as a major barrier for patients. One participant noted, *"Even when I want to do the test, it's either not available or the patient can't afford it—it's frustrating."* This logistical strain often discouraged routine incorporation of molecular diagnostics, especially in public hospitals or low-resource settings.

A third theme was *Educational and Training Gaps*, highlighting a perceived lack of adequate training in genomics during medical education and continuing professional development. Participants consistently reported discomfort in interpreting complex genetic reports, especially those with variants of uncertain significance. Several expressed the need for structured workshops or institutional support. The subthemes included insufficient genomic literacy and the desire for more targeted, case-based learning sessions.

Ethical and Emotional Dilemmas also surfaced, as clinicians described emotional tension in navigating conversations about molecular results. Many found it difficult to manage patient expectations, especially when test results did not translate into actionable treatment options. Ambiguous results led to anxiety among both patients and clinicians, creating a communication challenge. As one clinician shared, *"Explaining a test result that doesn't lead to a treatment feels like giving them false hope."* Others mentioned their own emotional burden when patients questioned the value of an expensive test that ultimately had limited clinical consequence.

The final theme identified was *Systemic and Policy-Driven Barriers*. A consistent concern across participants was the lack of standardized guidelines for when and how to order molecular tests. This created variation in practice patterns and uncertainty about medico-legal implications. Additionally, inconsistent reimbursement policies and unclear insurance coverage further discouraged clinicians from recommending these tests routinely. Participants emphasized the need for national protocols and clearer institutional directives to guide practice. Together, these findings underscore a multifactorial reality in which personal knowledge, system infrastructure, patient resources, and policy gaps collectively influence the integration of molecular biomarker testing into clinical oncology practice. The nuanced interplay of these factors reflects the need for targeted, multidimensional interventions to address the challenges clinicians face on the front lines of precision oncology.

DISCUSSION

The findings from this qualitative study offer an important window into the clinical realities faced by oncology clinicians in the Lahore region when incorporating molecular biomarker testing into cancer care. These perspectives, situated within a low-to-middle-income country (LMIC) context, underscore both globally acknowledged barriers and region-specific challenges. The themes generated—ranging from knowledge gaps to systemic obstacles—align in many ways with international research, but they also add culturally and infrastructurally grounded insights that enrich global understanding of molecular diagnostic implementation. The theme of limited awareness and variable understanding of biomarker utility is consistent with earlier studies, which found that even in high-income settings, clinicians may struggle to keep pace with the expanding biomarker landscape (16,17). The reported confusion surrounding which biomarkers are actionable or clinically meaningful mirrors similar concerns raised in precision oncology programs, where education and decision-support tools were found to be essential for integration (18). Clinicians' hesitancy to order tests when the clinical impact is uncertain underscores a persistent knowledge gap that educational interventions alone may not fully resolve without being tailored to real-world clinical decision pathways.

Operational challenges such as delayed turnaround times and cost barriers were particularly emphasized, reflecting persistent logistical inequities in LMIC settings. While centralized molecular testing hubs have been proposed in resource-constrained contexts to improve efficiency and accuracy (19), such infrastructure is largely absent in many parts of Pakistan. These barriers mirror the challenges of EHR integration and data harmonization in more technologically developed health systems, where poor interoperability also hampers effective testing and reporting (20). The findings around emotional and ethical dilemmas, particularly regarding patient communication and clinician distress, contribute to a relatively underexplored aspect of precision oncology literature. The emotional burden of discussing ambiguous or unactionable results has been echoed in U.S.-based studies where both clinicians and patients express a desire for simpler, clearer communication around test utility and prognosis (21). This emotional labor is particularly taxing when coupled with financial limitations that restrict access to follow-up care, creating moral dilemmas for clinicians who must deliver results without the resources to act on them. Policy-level barriers such as the absence of standardized testing guidelines and reimbursement uncertainty were also major impediments to implementation. Similar concerns have been documented in broader regional efforts across Europe and North America, where testing practices vary widely due to non-uniform protocols (22). These challenges point to a global need for structured

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frameworks, such as the ESMO Scale for Clinical Actionability of molecular Targets (ESCAT), that can be adapted locally and supported by policy reform (23).

A notable strength of this study lies in its focus on a clinician population within an LMIC context, addressing a significant gap in the existing literature which predominantly reflects high-income settings. The depth and richness of qualitative data allowed for a contextualized understanding of challenges, informed by lived experiences. Moreover, the use of a robust analytic framework and validation techniques such as member checking enhanced the credibility and transferability of findings. However, the study does have limitations. First, being limited to one geographical region restricts the generalizability of results to other parts of Pakistan or similar contexts. Second, the potential for selection bias exists, as those more engaged with biomarker testing may have been more willing to participate. Additionally, given the rapid evolution of molecular oncology, findings may quickly become outdated unless regularly reassessed. Future research should focus on longitudinal assessments of clinician adaptation to new testing protocols, as well as pilot interventions that integrate clinical decision support systems or structured training modules. Evaluations of policy implementation, such as national genomic testing guidelines or institutional pathway models like the 4R Oncology model, could offer further actionable insights (24,25). Additionally, mixed-methods research incorporating patient perspectives could complement clinician narratives to design more holistic and feasible integration strategies. In conclusion, this study adds to a growing body of literature emphasizing that the successful implementation of molecular biomarker testing is not solely a technical endeavor but a deeply human, institutional, and systemic challenge. Addressing these barriers will require not only educational initiatives and infrastructure investments but also sustained engagement with clinicians' practical and emotional realities.

CONCLUSION

This study illuminated the complex interplay of knowledge, infrastructure, and systemic barriers influencing oncology clinicians' adoption of molecular biomarker testing in routine cancer care in Lahore. By capturing their lived experiences, the research highlights an urgent need for targeted educational initiatives, infrastructure development, and policy standardization. These findings offer actionable insights to strengthen precision oncology integration in resource-constrained settings, ensuring more equitable and effective cancer care.

AUTHOR CONTRIBUTION

Author	Contribution
Ariba Shah*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Hafsa Hameed Thakur	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Amna Noor	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Nighat Fatima	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Irfan Ishaque	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Aeman Mumtaz	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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