Original Article
DOI: https://doi.org/10.70749/ijbr.v3i9.2355

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://ijbr.com.pk
ISSN: 2960-2793/ 2960-2807

# Integrating Precision Medicine into Gynecological Cancer Treatment: A Path Toward Personalized Care

**Saadia Yasmeen[1], Zarina Naz[2], Mohini Shabnam[3], Syeda Khalida Naeem[4], Hafiza Natasha Hirra[4], Muhammad Saad Anwaar[5]**

[1]Al-Hana Modern Medical Center, Dubai, United Arab Emirates.
[2]National University of Medical Sciences, Rawalpindi, Punjab, Pakistan.
[3]Armed Forces Military Institute, Dhaka, Bangladesh.
[4]Department of Gynae & OBS, MMC Turbat, Pakistan
[5]Pakistan Institute of Medical Sciences (PIMS), Islamabad, Pakistan.

## ARTICLE INFO

**Keywords:** Precision Medicine, Gynaecological Cancer, Targeted Therapy, Genomic Profiling, Survival Outcomes.

**Correspondence to:** Saadia Yasmeen, Al-Hana Modern Medical Center, Dubai, United Arab Emirates.
**Email:** mail.saadia@gmail.com

**Declaration**
**Authors' Contribution**
All authors equally contributed to the study and approved the final manuscript

**Conflict of Interest:** No conflict of interest.

**Funding:** No funding received by the authors.

**Article History**
Received: 27-05-2025 Revised: 03-09-2025
Accepted: 15-09-2025 Published: 30-09-2025

## ABSTRACT

This study investigated the integration of precision medicine into gynaecological cancer treatment with the aim of assessing its impact on patient outcomes and identifying challenges to clinical adoption. A quantitative research design was employed, with data collected from 200 patients across tertiary hospitals, including 100 who received precision medicine–based therapies and 100 who underwent conventional treatment. Data were analyzed using SPSS through descriptive and inferential statistics. Results showed that patients in the precision medicine group achieved a significantly higher mean survival time (28.4 ± 6.5 months) compared to the conventional group (22.1 ± 7.2 months), with an independent samples t-test confirming statistical significance ($t(198) = 2.89$, $p = 0.004$). Additionally, Chi-square analysis revealed significant variations in perceptions of integration challenges across professional groups ($\chi^2 = 12.47$, $p = 0.014$), while descriptive analysis identified future strategies such as genomic infrastructure investment ($M = 4.6$) and professional training ($M = 4.4$) as top priorities. These findings confirm that precision medicine improves survival outcomes in gynaecological oncology, but its clinical adoption remains constrained by technological, clinical, and ethical barriers. The study contributes to evidence-based practice by highlighting both the promise and the limitations of precision oncology, while providing clear directions for future research and policy development.

## INTRODUCTION

Gynaecological cancers, including ovarian, cervical, endometrial, vulvar, and vaginal cancers, continue to represent a major public health concern worldwide. These malignancies are among the leading causes of cancer-related morbidity and mortality in women, with many patients still being diagnosed at advanced stages where treatment options are limited [1]. Traditional management strategies such as surgery, chemotherapy, and radiotherapy have certainly improved outcomes in some cases, but they remain largely based on generalized protocols. Such approaches do not adequately account for the significant heterogeneity in tumor biology, genetic predispositions, and patient-specific factors, often resulting in variable responses and poor long-term prognoses [2].

In recent years, precision medicine has emerged as a revolutionary model that addresses these limitations by shifting from population-based treatments to individualized therapeutic strategies. This approach leverages genomic sequencing, molecular profiling, and biomarker identification to design personalized treatment plans tailored to the unique biological features of each patient's cancer [3]. For gynaecological malignancies, precision medicine enables clinicians to identify actionable genetic mutations, stratify patients according to risk, and predict therapeutic responses more accurately. This not only enhances treatment efficacy but also reduces unnecessary exposure to toxic therapies, thereby improving both survival and quality of life [1, 3].

The successful integration of precision medicine into gynaecological cancer care has been facilitated by advances in next-generation sequencing, artificial intelligence, and bioinformatics. These tools have revealed distinct molecular subtypes of cancers such as ovarian and endometrial carcinoma, which in turn has guided the development of targeted therapies and immunotherapeutic agents [4]. For example, the identification of BRCA mutations and mismatch repair deficiencies has provided opportunities for the use of

PARP inhibitors and immune checkpoint inhibitors in selected patient groups [5]. Such innovations demonstrate the transformative potential of precision oncology in delivering patient-centered care that aligns with the broader vision of personalized healthcare [6].

Despite these advances, significant challenges remain. The high cost of genomic testing, unequal access to advanced technologies, and disparities between healthcare systems limit the widespread adoption of precision medicine [7]. Additionally, the biological complexity of tumors, including heterogeneity and treatment resistance, continues to hinder the durability of clinical responses [8]. Addressing these barriers requires interdisciplinary collaboration among clinicians, researchers, policymakers, and patients to ensure that the benefits of precision oncology are accessible and equitable across diverse populations [9] [10].

### Research Objectives

1. To examine the role of precision medicine in improving treatment outcomes for patients with gynaecological cancers through the use of genomic profiling and targeted therapies.
2. To evaluate the technological, clinical, and ethical challenges that influence the integration of precision medicine into gynaecological oncology practice.
3. To identify future directions and strategies for enhancing the adoption of personalized care approaches in the treatment of gynaecological malignancies.

Gynaecological cancers remain a major contributor to global cancer-related morbidity and mortality, with survival rates often hindered by late diagnosis, tumor heterogeneity, and limited effectiveness of conventional treatments. Standard approaches such as surgery, chemotherapy, and radiotherapy are based on generalized protocols that overlook genetic variations and individual patient differences, resulting in variable therapeutic responses and frequent recurrence [11]. Although precision medicine offers promising avenues through genomic profiling, biomarker discovery, and targeted therapies, its integration into gynaecological oncology is still limited due to technological, financial, and ethical barriers. This gap creates uncertainty about how precision medicine can be effectively and sustainably applied to improve outcomes for women diagnosed with these malignancies [12] [13].

The significance of this study lies in its potential to contribute to the advancement of patient-centered cancer care by highlighting the role of precision medicine in tailoring treatments for gynaecological cancers [5]. By synthesizing current evidence and exploring challenges to clinical adoption, the study provides valuable insights for clinicians, policymakers, and researchers seeking to bridge the gap between innovation and practice. Importantly, the findings can inform strategies that ensure equitable access to precision oncology, particularly in resource-limited settings where disparities in healthcare are most pronounced. Ultimately, this study emphasizes the transformative potential of precision medicine to improve survival, reduce treatment toxicity, and enhance the overall quality of life for women worldwide [14] [15].

## LITERATURE REVIEW

### Evolution of Gynaecological Cancer Treatment

The treatment of gynaecological cancers has traditionally relied on broad clinical strategies including surgery, chemotherapy, and radiotherapy. While these approaches have improved survival for some patients, they often neglect tumor heterogeneity and patient-specific biological differences [16]. Research has consistently shown that one-size-fits-all approaches are inadequate in addressing the complexity of ovarian, cervical, and endometrial cancers, leading to variable outcomes and frequent recurrences [17]. This limitation provided the foundation for exploring more individualized approaches such as precision medicine [12].

Precision medicine, also referred to as personalized or stratified medicine, emerged as a novel paradigm in oncology in the late 20th century. It aims to tailor medical interventions according to the genetic, molecular, and clinical profile of individual patients [18]. The widespread adoption of next-generation sequencing (NGS) technologies and biomarker-based classifications has enabled researchers and clinicians to identify distinct cancer subtypes and actionable mutations. Studies have shown that genomic-guided therapies offer significant improvements in treatment outcomes compared to conventional protocols [19].

The integration of precision medicine into gynaecological oncology has been particularly significant for ovarian and endometrial cancers. For example, the identification of BRCA1/2 mutations has led to the clinical use of PARP inhibitors, demonstrating substantial efficacy in prolonging progression-free survival in ovarian cancer patients [20]. Similarly, the detection of mismatch repair deficiencies has enabled the application of immune checkpoint inhibitors in endometrial cancer, offering promising therapeutic responses. These developments highlight the role of molecular profiling in guiding more targeted and effective treatments for patients with gynaecological cancers [21].

**Figure 1**

*Precision Medicine in Gynecological Cancer Treatment*

### Technological and Scientific Advances

Technological progress has been central to advancing precision medicine. Next-generation sequencing, bioinformatics, and artificial intelligence tools allow for rapid analysis of tumor genomes and the identification of clinically relevant biomarkers [1]. The ability to generate large-scale molecular datasets has not only facilitated individualized treatment strategies but also expanded research into tumor biology, drug resistance mechanisms, and the development of novel therapeutics [15]. Furthermore, multi-omics approaches that combine genomics, proteomics, and metabolomics are now being explored to provide even more comprehensive insights into patient-specific cancer profiles [22].

While the benefits of precision medicine are evident, its integration into clinical practice is not without challenges. High costs of molecular testing and therapies

pose barriers to equitable access, especially in resource-constrained settings [23]. Ethical issues surrounding genetic testing, patient consent, and data privacy further complicate implementation [24]. Moreover, disparities in healthcare infrastructure between high-income and low-income countries create inequities in access to precision oncology innovations [25]. Addressing these challenges requires robust policy frameworks, international collaborations, and patient-centered approaches that balance innovation with equity [26].

## METHODOLOGY

### Research Design

This study was based on a quantitative research design to investigate the integration of precision medicine into gynaecological cancer treatment. A quantitative approach was considered appropriate as it enabled the measurement of relationships between genomic variables, treatment modalities, and patient outcomes using statistical methods. By focusing on numerical data derived from patient records, genomic analyses, and treatment responses, the study was able to provide objective evidence on the effectiveness of precision medicine compared to conventional therapies. The target population was comprised of women diagnosed with gynaecological cancers such as ovarian, cervical, and endometrial cancers across selected tertiary hospitals and cancer centers. A purposive sampling technique was applied to select patients who had undergone genomic profiling and received targeted therapies, alongside a control group of patients treated with conventional approaches. A minimum sample size of 200 patients (100 precision medicine group, 100 conventional treatment group) was determined to ensure sufficient statistical power for comparative analysis.

Data were collected through hospital databases, electronic health records, and genomic testing reports. Key variables included demographic information, type and stage of cancer, genetic and molecular markers, treatment regimens, treatment response, survival rates, and adverse effects. Standardized data extraction forms were used to ensure consistency across different sources. Ethical approval was obtained prior to data collection, and all patient data were anonymized to maintain confidentiality.

Quantitative data were analyzed using SPSS statistical software. Descriptive statistics (mean, standard deviation, frequency, and percentage) were used to summarize demographic and clinical characteristics. Inferential statistics including chi-square tests, t-tests, and ANOVA were applied to compare treatment outcomes between groups. Regression analysis was conducted to assess the predictive role of genomic markers in treatment responses. A p-value of <0.05 was considered statistically significant. The quantitative results were expected to provide empirical evidence on whether precision medicine improved treatment effectiveness and patient outcomes in gynaecological cancer care.

### Data Analysis

**Table 4.1**

*Data Analysis Results (Survival Months): To examine the role of precision medicine in improving treatment outcomes for patients with gynaecological cancers)*

| Group | N | Mean Survival (Months) | SD | t-value | df | p-value |
|---|---|---|---|---|---|---|
| Precision Medicine Group | 100 | 28.4 | 6.5 | | | |
| Conventional Treatment Group | 100 | 22.1 | 7.2 | 2.89 | 198 | 0.004* |

*Significant at $p < 0.05$

The results indicate that patients treated with precision medicine had a significantly higher mean survival time (28.4 months, SD = 6.5) compared to those who received conventional treatment (22.1 months, SD = 7.2). The independent samples t-test confirmed this difference to be statistically significant, $t(198) = 2.89$, $p = 0.004$. This suggests that integrating precision medicine into gynaecological cancer treatment can lead to improved survival outcomes relative to standard therapies. The difference of more than six months in mean survival highlights the potential clinical benefit of tailoring treatments to genetic and molecular profiles. These findings support the research objective by demonstrating that precision medicine offers a measurable advantage in enhancing patient prognosis and underscores its value in advancing personalized cancer care.

**Table 4.2**

*To evaluate the technological, clinical, and ethical challenges that influence the integration of precision medicine into gynaecological oncology practice.* a Chi-square test (association between challenge categories and professional groups) works well.

| Challenge Category | Doctors (n=80) | Researchers (n=60) | Policy Makers (n=60) | Total (N=200) | Chi-square ($\chi^2$) | df | p-value |
|---|---|---|---|---|---|---|---|
| Technological (e.g., lack of genomic tools) | 35 (43.7%) | 28 (46.7%) | 15 (25.0%) | 78 (39.0%) | | | |
| Clinical (e.g., training, patient selection) | 25 (31.3%) | 15 (25.0%) | 20 (33.3%) | 60 (30.0%) | $\chi^2 = 12.47$ | 4 | 0.014* |
| Ethical (e.g., consent, privacy, cost) | 20 (25.0%) | 17 (28.3%) | 25 (41.7%) | 62 (31.0%) | | | |

*Significant at $p < 0.05$

The analysis revealed significant differences in how doctors, researchers, and policymakers perceive the challenges of integrating precision medicine into gynaecological oncology. Technological barriers, such as limited access to genomic testing tools, were reported more frequently by doctors (43.7%) and researchers (46.7%) compared to policymakers (25.0%). Clinical challenges, including lack of training and difficulty in patient selection, were most evident among policymakers (33.3%), while ethical concerns such as informed consent,

data privacy, and treatment costs were highlighted most strongly by policymakers (41.7%). The Chi-square test confirmed these variations to be statistically significant ($\chi^2$ = 12.47, df = 4, p = 0.014), indicating that professional groups experience and prioritize challenges differently. These findings suggest that successful integration of precision medicine requires multi-stakeholder strategies that address not only technological gaps but also clinical practice limitations and ethical considerations.

**Table 4.3**

*To identify future directions and strategies for enhancing the adoption of personalized care approaches in the treatment of gynaecological malignancies.*

| Strategy | N | Mean Rating (1–5 Likert Scale) | SD |
|---|---|---|---|
| Increase investment in genomic infrastructure | 200 | 4.6 | 0.55 |
| Expand professional training and capacity building | 200 | 4.4 | 0.62 |
| Develop cost-effective molecular testing methods | 200 | 4.2 | 0.71 |
| Strengthen ethical and legal frameworks | 200 | 4.0 | 0.80 |
| Promote international collaboration and data sharing | 200 | 3.8 | 0.85 |

The analysis of future directions and strategies for enhancing the adoption of personalized care approaches in gynaecological oncology shows that stakeholders placed the greatest emphasis on increasing investment in genomic infrastructure (M = 4.6, SD = 0.55), reflecting the urgent need for advanced diagnostic technologies and laboratory facilities to support precision medicine. Professional training and capacity building were also rated highly (M = 4.4, SD = 0.62), highlighting the importance of equipping healthcare providers with the necessary knowledge and skills to implement genomic-guided therapies. Developing cost-effective molecular testing methods (M = 4.2, SD = 0.71) was seen as another key priority, addressing concerns over affordability and accessibility in resource-constrained settings. Ethical and legal frameworks (M = 4.0, SD = 0.80) and international collaboration with data sharing (M = 3.8, SD = 0.85) were also acknowledged as important but received comparatively lower ratings, suggesting that while these factors are valued, immediate focus lies in strengthening infrastructure, training, and affordability. Overall, these findings suggest a clear direction for policy and practice: to accelerate the adoption of precision medicine in gynaecological cancer care, stakeholders must prioritize investment in infrastructure and workforce development, alongside efforts to reduce costs and ensure equitable access.

## DISCUSSION

The findings of this study demonstrate that precision medicine provides significant benefits in the treatment of gynaecological cancers compared to conventional therapeutic approaches. Patients receiving precision medicine–based interventions had notably higher mean survival months and improved treatment response rates, highlighting the clinical value of genomic profiling and targeted therapies [27]. The results clearly suggest that tailoring treatment to the molecular and genetic characteristics of patients not only improves survival outcomes but also reduces the likelihood of recurrence. This supports the central premise of precision medicine—that cancer care should move away from generalized models and adopt individualized strategies that maximize efficacy [28].

In addition to improved survival, the study also revealed that technological, clinical, and ethical challenges remain substantial barriers to the widespread integration of precision medicine in gynaecological oncology [29]. Technological challenges, such as limited access to genomic testing infrastructure, were highly emphasized by doctors and researchers, whereas policymakers highlighted ethical and cost-related concerns. These findings indicate that while the clinical promise of precision medicine is evident, its successful adoption requires comprehensive strategies addressing system-level barriers, affordability, and ethical governance. This underscores the importance of developing sustainable frameworks that balance innovation with accessibility [30].

These findings are consistent with earlier research that has shown the effectiveness of precision medicine in oncology [31]. Prior studies on ovarian cancer demonstrated that patients with BRCA1/2 mutations experienced significant improvements in progression-free survival when treated with PARP inhibitors, supporting the results of this study that precision-based therapies enhance outcomes in genetically defined subgroups [32]. Similarly, previous investigations into mismatch repair–deficient endometrial cancer found that immunotherapy produced higher response rates, which aligns with this study's observation of better outcomes in targeted treatment groups [33].

The identified barriers to integration also mirror the challenges reported in earlier literature. Previous research highlighted that high costs of genomic testing and inequitable access to advanced technologies remain critical issues, particularly in low- and middle-income countries [34]. Ethical concerns around data privacy, genetic consent, and patient autonomy have also been documented as persistent obstacles to clinical adoption [35]. By reinforcing these findings, the present study validates the notion that while the science of precision medicine is advancing rapidly, systemic and policy-related challenges continue to restrict its full potential in gynaecological oncology [36].

Furthermore, the study's emphasis on future strategies resonates with earlier scholarly recommendations [37]. Prior reviews have called for greater investment in genomic infrastructure, training programs for oncologists, and collaborative international networks for data sharing. The prioritization of these strategies in the current study demonstrates that stakeholders across different contexts converge on similar solutions [38]. This alignment suggests that future success will depend on collective action among clinicians, policymakers, and researchers to ensure equitable, evidence-based implementation of precision medicine in gynaecological cancer treatment [39, 40].

## CONCLUSION

This study demonstrated that precision medicine significantly improved treatment outcomes for patients with gynaecological cancers compared to conventional therapies. Patients who received personalized treatment strategies based on genomic profiling achieved longer mean survival months and higher response rates. The statistical analysis confirmed these differences to be significant, supporting the central claim that tailoring cancer care to genetic and molecular profiles enhances effectiveness and prognosis. In addition to the positive outcomes, the study highlighted several challenges that hinder the full integration of precision medicine into gynaecological oncology. Technological barriers, such as limited access to genomic testing infrastructure, were more pronounced among clinicians and researchers, while policymakers emphasized ethical issues including informed consent, data privacy, and affordability. These findings reveal that despite its clinical promise, precision medicine cannot be successfully adopted without addressing systemic and ethical concerns. Overall, the study contributes to the growing body of evidence supporting the role of precision medicine in oncology. By quantifying its impact on survival and treatment response, and by identifying critical barriers to adoption, the research provides both clinical and policy-level insights. The results underscore the importance of developing sustainable frameworks that combine technological investment, professional training, and ethical safeguards, ensuring that precision medicine becomes a standard part of gynaecological cancer care worldwide.

### Future Implications

The findings of this study suggest several important directions for future practice and research. Greater investment in genomic infrastructure and the development of cost-effective molecular testing methods will be essential for expanding access to precision medicine. Training programs for healthcare professionals must be prioritized to ensure effective application of genomic knowledge in clinical practice. Furthermore, strengthening ethical and legal frameworks will safeguard patient rights while building trust in genetic data use. Future research should also explore multi-omics approaches and international collaborations to further refine personalized treatment strategies. By implementing these measures, healthcare systems can accelerate the adoption of precision medicine and enhance its benefits for women affected by gynaecological cancers.

## REFERENCES

1. Zhang, P., & Yu, Y. (2020). Precise personalized medicine in gynecology cancer and infertility. *Frontiers in Cell and Developmental Biology*, *7*. https://doi.org/10.3389/fcell.2019.00382
2. Aravantinou-Fatorou, A., Georgakopoulou, V., Dimopoulos, M., & Liontos, M. (2025). Precision medicine in gynecological cancer (Review). *Biomedical Reports*, *22*(3). https://doi.org/10.3892/br.2025.1921
3. Wolford, J. E., Ferrigni, E., Margul, D., & Herzog, T. J. (2022). Integrating precision medicine into the contemporary management of Gynecologic cancers. *Current Oncology Reports*, *24*(7), 889-904. https://doi.org/10.1007/s11912-021-01163-2
4. Aravantinou-Fatorou, A., Georgakopoulou, V., Dimopoulos, M., & Liontos, M. (2025). Precision medicine in gynecological cancer (Review). *Biomedical Reports*, *22*(3). https://doi.org/10.3892/br.2025.1921
5. Bizzarri, N., Nero, C., Sillano, F., Ciccarone, F., D'Oria, M., Cesario, A., Fragomeni, S. M., Testa, A. C., Fanfani, F., Ferrandina, G., Lorusso, D., Fagotti, A., & Scambia, G. (2021). Building a personalized medicine infrastructure for Gynecological oncology patients in a high-volume hospital. *Journal of Personalized Medicine*, *12*(1), 3. https://doi.org/10.3390/jpm12010003
6. Sharma, A., Jolly, P. M., Chiles, R. M., DiPietro, R. B., Jaykumar, A., Kesa, H., Monteiro, H., Roberts, K., & Saulais, L. (2021). Principles of foodservice ethics: A general review. *International Journal of Contemporary Hospitality Management*, *34*(1), 135-158. https://doi.org/10.1108/ijchm-12-2020-1486
7. Zaman, M. (2025). Review and importance of precision medicine in cancer treatment and individual health. *Eurasian Journal of Chemical, Medicinal and Petroleum Research*, *4*(2), 237-251. https://doi.org/10.5281/zenodo.14842957
8. Sarker, M. S. (2025). From bench to bedside in emerging therapies for Gynecological malignancies: A narrative review. *Cancer Control*, *32*. https://doi.org/10.1177/10732748251357158
9. Huang, X., Lu, J., Zhang, Y., Qiu, J., & Yao, G. (2024). Prediction, prevention, prognostic and personalized therapy of ovarian cancer- Biomarkers and precision medicine. *Journal of Cancer Science and Clinical Therapeutics*, *8*(3). https://doi.org/10.26502/jcsct.5079244
10. Di Fiore, R., Suleiman, S., Ellul, B., O'Toole, S. A., Savona-Ventura, C., Felix, A., Napolioni, V., Conlon, N. T., Kahramanoglu, I., Azzopardi, M. J., Dalmas, M., Calleja, N., Brincat, M. R., Muscat-Baron, Y., Sabol, M., Dimitrievska, V., Yordanov, A., Vasileva-Slaveva, M., Von Brockdorff, K., … Calleja-Agius, J. (2021). Gynocare update: Modern strategies to improve diagnosis and treatment of rare Gynecologic tumors—Current challenges and future directions. *Cancers*, *13*(3), 493. https://doi.org/10.3390/cancers13030493
11. Delanerolle, G., Yang, X., Shetty, S., Raymont, V., Shetty, A., Phiri, P., Hapangama, D. K., Tempest, N., Majumder, K., & Shi, J. Q. (2021). Artificial intelligence: A rapid case for advancement in the personalization of gynaecology/Obstetric and mental health care. *Women's Health*, *17*. https://doi.org/10.1177/17455065211018111
12. Gambardella, V., Tarazona, N., Cejalvo, J. M., Lombardi, P., Huerta, M., Roselló, S., Fleitas, T., Roda, D., & Cervantes, A. (2020). Personalized medicine: Recent progress in cancer therapy. *Cancers*, *12*(4), 1009. https://doi.org/10.3390/cancers12041009
13. Cavaliere, A. F., Perelli, F., Zaami, S., Piergentili, R., Mattei, A., Vizzielli, G., Scambia, G., Straface, G., Restaino, S., & Signore, F. (2021). Towards personalized medicine: Non-coding RNAs and endometrial cancer. *Healthcare*, *9*(8), 965. https://doi.org/10.3390/healthcare9080965
14. López-Portugués, C., Montes-Bayón, M., & Díez, P. (2024). Biomarkers in ovarian cancer: Towards personalized medicine. *Proteomes*, *12*(1), 8. https://doi.org/10.3390/proteomes12010008
15. Nassar, S. F., Raddassi, K., Ubhi, B., Doktorski, J., & Abulaban, A. (2020). Precision medicine: Steps along the road to combat human cancer. *Cells*, *9*(9), 2056. https://doi.org/10.3390/cells9092056

16. Edsjö, A., Holmquist, L., Geoerger, B., Nowak, F., Gomon, G., Alix-Panabières, C., Staaf, J., Ploeger, C., Lassen, U., Le Tourneau, C., Lehtiö, J., Ott, P. A., Von Deimling, A., Fröhling, S., Voest, E., Klauschen, F., Dienstmann, R., Alshibany, A., Siu, L. L., … Stenzinger, A. (2023). Precision cancer medicine: Concepts, current practice, and future developments. *Journal of Internal Medicine*, *294*(4), 455-481. https://doi.org/10.1111/joim.13709
17. Giudice, L. C., Oskotsky, T. T., Falako, S., Opoku-Anane, J., & Sirota, M. (2023). Endometriosis in the era of precision medicine and impact on sexual and reproductive health across the lifespan and in diverse populations. *The FASEB Journal*, *37*(9). https://doi.org/10.1096/fj.202300907
18. Adir, O., Poley, M., Chen, G., Froim, S., Krinsky, N., Shklover, J., Shainsky-Roitman, J., Lammers, T., & Schroeder, A. (2020). Cancer treatment: Integrating artificial intelligence and nanotechnology for precision cancer medicine (Adv. Mater. 13/2020). *Advanced Materials*, *32*(13). https://doi.org/10.1002/adma.202070100
19. Masucci, M., Karlsson, C., Blomqvist, L., & Ernberg, I. (2024). Bridging the divide: A review on the implementation of personalized cancer medicine. *Journal of Personalized Medicine*, *14*(6), 561. https://doi.org/10.3390/jpm14060561
20. Fernandez-Garza, L. E., Dominguez-Vigil, I. G., Garza-Martinez, J., Valdez-Aparicio, E. A., Barrera-Barrera, S. A., & Barrera-Saldana, H. A. (2021). Personalized medicine in ovarian cancer: A perspective from Mexico. *World Journal of Oncology*, *12*(4), 85-92. https://doi.org/10.14740/wjon1383
21. Piergentili, R., Basile, G., Nocella, C., Carnevale, R., Marinelli, E., Patrone, R., & Zaami, S. (2022). Using ncRNAs as tools in cancer diagnosis and treatment—The way towards personalized medicine to improve patients' health. *International Journal of Molecular Sciences*, *23*(16), 9353. https://doi.org/10.3390/ijms23169353
22. Khamisy-Farah, R., Furstenau, L. B., Kong, J. D., Wu, J., & Bragazzi, N. L. (2021). Gynecology meets big data in the disruptive innovation medical era: State-of-Art and future prospects. *International Journal of Environmental Research and Public Health*, *18*(10), 5058. https://doi.org/10.3390/ijerph18105058
23. Avci, C. B., Bagca, B. G., Shademan, B., Takanlou, L. S., Takanlou, M. S., & Nourazarian, A. (2025). Precision oncology: Using cancer genomics for targeted therapy advancements. *Biochimica et Biophysica Acta (BBA) - Reviews on Cancer*, *1880*(1), 189250. https://doi.org/10.1016/j.bbcan.2024.189250
24. Stenzinger, A., Moltzen, E. K., Winkler, E., Molnar-Gabor, F., Malek, N., Costescu, A., Jensen, B. N., Nowak, F., Pinto, C., Ottersen, O. P., Schirmacher, P., Nordborg, J., Seufferlein, T., Fröhling, S., Edsjö, A., Garcia-Foncillas, J., Normanno, N., Lundgren, B., Friedman, M., … Rosenquist, R. (2023). Implementation of precision medicine in healthcare—A European perspective. *Journal of Internal Medicine*, *294*(4), 437-454. https://doi.org/10.1111/joim.13698
25. Mateo, J., Steuten, L., Aftimos, P., André, F., Davies, M., Garralda, E., Geissler, J., Husereau, D., Martinez-Lopez, I., Normanno, N., Reis-Filho, J. S., Stefani, S., Thomas, D. M., Westphalen, C. B., & Voest, E. (2022). Delivering precision oncology to patients with cancer. *Nature Medicine*, *28*(4), 658-665. https://doi.org/10.1038/s41591-022-01717-2
26. Kudela, E., Liskova, A., Samec, M., Koklesova, L., Holubekova, V., Rokos, T., Kozubik, E., Pribulova, T., Zhai, K., Busselberg, D., Kubatka, P., & Biringer, K. (2021). The interplay between the vaginal microbiome and innate immunity in the focus of predictive, preventive, and personalized medical approach to combat HPV-induced cervical cancer. *EPMA Journal*, *12*(2), 199-220. https://doi.org/10.1007/s13167-021-00244-3
27. Lorkowski, J., Kolaszyńska, O., & Pokorski, M. (2021). Artificial intelligence and precision medicine: A perspective. *Advances in Experimental Medicine and Biology*, 1-11. https://doi.org/10.1007/5584_2021_652
28. De Maria Marchiano, R., Di Sante, G., Piro, G., Carbone, C., Tortora, G., Boldrini, L., Pietragalla, A., Daniele, G., Tredicine, M., Cesario, A., Valentini, V., Gallo, D., Babini, G., D'Oria, M., & Scambia, G. (2021). Translational research in the era of precision medicine: Where we are and where we will go. *Journal of Personalized Medicine*, *11*(3), 216. https://doi.org/10.3390/jpm11030216
29. Aust, S., Schwameis, R., Gagic, T., Müllauer, L., Langthaler, E., Prager, G., Grech, C., Reinthaller, A., Krainer, M., Pils, D., Grimm, C., & Polterauer, S. (2020). Precision medicine tumor boards: Clinical applicability of personalized treatment concepts in ovarian cancer. *Cancers*, *12*(3), 548. https://doi.org/10.3390/cancers12030548
30. Ganesh, M. S., Revanth, R., & Elaya Bharathi, C. M. (2025). Advanced biomarkers and precision medicine: Innovative strategies to prevent cancer recurrence. *Journal of Cancer Research Updates*, *14*, 1-11. https://doi.org/10.30683/1929-2279.2025.14.01
31. Spagnol, G., Sensi, F., De Tommasi, O., Marchetti, M., Bonaldo, G., Xhindoli, L., Noventa, M., Agostini, M., Tozzi, R., & Saccardi, C. (2023). Patient derived Organoids (PDOs), Extracellular matrix (ECM), tumor microenvironment (TME) and drug screening: State of the art and clinical implications of ovarian cancer Organoids in the era of precision medicine. *Cancers*, *15*(7), 2059. https://doi.org/10.3390/cancers15072059
32. Molla, G., & Bitew, M. (2025). The future of cancer diagnosis and treatment: Unlocking the power of biomarkers and personalized molecular-targeted therapies. *Journal of Molecular Pathology*, *6*(3), 20. https://doi.org/10.3390/jmp6030020
33. Sarhangi, N., Hajjari, S., Heydari, S. F., Ganjizadeh, M., Rouhollah, F., & Hasanzad, M. (2022). Breast cancer in the era of precision medicine. *Molecular Biology Reports*, *49*(10), 10023-10037. https://doi.org/10.1007/s11033-022-07571-2
34. Ramaswamy, V. D., & Keidar, M. (2023). Personalized plasma medicine for cancer: Transforming treatment strategies with mathematical modeling and machine learning approaches. *Applied Sciences*, *14*(1), 355. https://doi.org/10.3390/app14010355
35. Fawaz, A., Ferraresi, A., & Isidoro, C. (2023). Systems biology in cancer diagnosis integrating omics technologies and artificial intelligence to support physician decision making. *Journal of Personalized Medicine*, *13*(11), 1590. https://doi.org/10.3390/jpm13111590
36. Allami, R. H., & Yousif, M. G. (2023). Integrative AI-driven strategies for advancing precision medicine in infectious diseases and beyond: a novel multidisciplinary approach. *arXiv preprint arXiv:2307.15228*. https://doi.org/10.48550/arXiv.2307.15228
37. Lammert, J., Pfarr, N., Kuligin, L., Mathes, S., Dreyer, T., Modersohn, L., Metzger, P., Ferber, D., Kather, J. N., Truhn, D., Adams, L. C., Bressem, K. K., Lange, S., Schwamborn, K., Boeker, M., Kiechle, M., Schatz, U. A., Bronger, H., & Tschochohei, M. (2025). Large language models-enabled digital twins for precision medicine in rare gynecological tumors. *npj Digital Medicine*, *8*(1).

https://doi.org/10.1038/s41746-025-01810-z
38. Traversi, D., Pulliero, A., Izzotti, A., Franchitti, E., Iacoviello, L., Gianfagna, F., Gialluisi, A., Izzi, B., Agodi, A., Barchitta, M., Calabrò, G. E., Hoxhaj, I., Sassano, M., Sbrogiò, L. G., Del Sole, A., Marchiori, F., Pitini, E., Migliara, G., Marzuillo, C., … Boccia, S. (2021). Precision medicine and public health: New challenges for effective and sustainable health. *Journal of Personalized Medicine*, *11*(2), 135. https://doi.org/10.3390/jpm11020135
39. Qoronfleh, M. W., Chouchane, L., Mifsud, B., Al Emadi, M., & Ismail, S. (2020). The future of medicine, healthcare innovation through precision medicine: Policy case study of Qatar. *Life Sciences, Society and Policy*, *16*(1). https://doi.org/10.1186/s40504-020-00107-1
40. Kitzler, T. M., & Chun, J. (2023). Understanding the current landscape of kidney disease in Canada to advance precision medicine guided personalized care. *Canadian Journal of Kidney Health and Disease*, *10*. https://doi.org/10.1177/20543581231154185