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Review

Advances in Precision Supportive and Palliative Care: Integrating Biomarkers, Digital Health, and AI to Personalize Symptom Management in Cancer Patients

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Abstract

Background: The landscape of supportive and palliative care is changing. While traditional symptom management has primarily relied on standardized protocols, we are now witnessing a shift driven by advances in precision medicine, biomarker discovery, digital technologies, and artificial intelligence (AI). These tools offer new ways to interpret, predict, and manage symptom experiences in cancer patients more personally. Objective: This article examines recent advancements in integrating biomarkers, AI-based tools, and digital health technologies into supportive and palliative care. It discusses how these innovations can facilitate more personalized and timely symptom management. Recent Insights: There is a growing use of biomarkers, such as inflammatory markers and pharmacogenomic indicators, to estimate symptom burden and guide therapy. At the same time, AI helps predict symptom trajectories and improve clinical decision-making. Digital tools, including ePROs [9], wearables, and remote monitoring systems, are playing an increasingly active role in delivering responsive care between visits. Still, significant gaps remain in implementation, particularly in settings with limited infrastructure or resources. Conclusion: Precision-based tools show great promise in enhancing individualized and timely symptom management and optimizing healthcare delivery. Bridging the gap between technological innovation and bedside application will require focused investment. However, the lack of access to the most basic palliative care services in many countries still hinders progress. Health systems globally should stimulate and prioritize the integration of essential palliative care services into cancer care as a core component, especially in settings with limited infrastructure or resources.

Introduction

Cancer care is undergoing a quiet but significant transformation. Personalization, once a distant ideal, is now becoming central to how care is designed and delivered. Advances in genomics, big data analytics, data science, and patient-centered technologies have enabled oncology to move beyond standard protocols and toward tailored treatment strategies. However, in the supportive and palliative care specialty, which is focused on easing suffering and improving quality of life, care models have often remained generalized and protocol-driven.

These conventional approaches, while often effective, may not fully address the complex, individual nature of symptom experiences in patients with advanced illnesses. Symptoms such as pain, fatigue, breathlessness, anorexia, and psychological distress are rarely uniform in their expression or their response to treatment. Their underlying causes are multifaceted, and their impact varies widely between individuals.

The growing integration of precision tools offers new possibilities for addressing this challenge. Biomarkers, artificial intelligence (AI), and digital health platforms are beginning to inform more personalized, timely approaches to symptom management. These tools enable the earlier identification of at-risk patients, more accurate predictions of symptom trajectories, and treatment strategies that reflect each patient's unique biological and psychosocial context.

This review highlights a few of the recent developments in

precision-based innovations in the field of supportive and palliative care:

• Biomarker-guided symptom prediction and individualized therapy selection

• AI-driven forecasting models and clinical decision support

• Digital platforms for real-time symptom tracking and remote monitoring

• Advances in pharmacology and procedural interventions

• Challenges in global implementation, with insights from models such as the Dana-Farber Cancer Institute

Bridging innovation and clinical application remains a key priority in modern medicine. By aligning symptoms care with the principles of precision medicine, supportive and palliative care can become not only more effective but also more responsive to the unique needs and goals of each patient.

Biomarkers in Symptom Prediction and Management

Biomarkers have long played a critical role in oncology, guiding diagnosis, prognosis, and treatment selection. In recent years, their relevance has expanded into supportive and palliative care, particularly in understanding, predicting, and managing symptom burden. This shift reflects a broader movement toward individualized care, where symptoms are no longer addressed solely through patient reports or clinician judgment, but also through biological insight. Symptoms such as fatigue, pain, cachexia, and psychological distress often arise from complex physiological mechanisms. Integrating biomarkers into routine symptom assessment may enable earlier recognition of distress, more precise targeting of therapies, and improved outcomes across a broad spectrum of patient experiences.

For example, cancer-related fatigue (CRF) [1], which is one of the most prevalent and challenging symptoms, has been linked to inflammatory processes. Elevated levels of markers such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor-alpha (TNF-α) have been associated with higher fatigue severity [2], even in patients who are otherwise in remission. These findings support the use of anti-inflammatory strategies [4], nutritional interventions [5], and tailored exercise programs informed by a patient's inflammatory profile. In the domain of pain management, pharmacogenomic markers are gaining increasing attention. Genetic variations in opioid receptors (e.g., OPRM1 A118G [3]) and cytochrome P450 enzymes (particularly CYP2D6) have been shown to influence opioid metabolism, efficacy, and side effect profiles. Incorporating such data into clinical practice may help optimize opioid selection and dosing, minimizing both undertreatment and toxicity.

Cachexia, a multifactorial syndrome involving weight loss, muscle wasting, and appetite suppression, remains a significant clinical concern. Biomarkers such as IL-1, IL-6, and growth differentiation factor-15 (GDF-15) have been associated with cachexia [16] severity and may serve as both prognostic indicators and therapeutic targets. Ongoing trials involving anti-GDF-15 therapies and anabolic agents increasingly use biomarker thresholds to guide patient selection and response monitoring. Neurocognitive and affective symptoms, including delirium, depression, and anxiety, are also being explored through a biomarker lens. Elevated levels of S100B protein, IL-8, and cortisol have been associated with increased vulnerability to these symptoms, especially in patients with systemic inflammation or brain metastases.

Integrating such markers into clinical pathways may support earlier intervention and help tailor both pharmacologic and non-pharmacologic strategies. Taken together, these developments point toward a future in which symptom management in cancer care becomes more biologically informed. Biomarkers offer the potential to move beyond generalized protocols and support a more dynamic, patient-specific approach, one that anticipates distress before it escalates and responds with greater precision.

AI and Predictive Models in Palliative Care

Artificial intelligence (AI) is beginning to transform the way care is delivered, not only in treatment planning but also in how symptoms are understood and managed. In supportive and palliative care, where early recognition of problems is key, AI tools are showing real promise [7]. These systems can help identify patterns, predict when symptoms may worsen, and even suggest the most effective ways to respond.

One of the biggest strengths of AI is its ability to look at large amounts of patient data over time. For example, machine learning models have been trained to predict events such as pain flare-ups, trouble breathing, or even confusion (delirium) before they occur. These models often utilize a combination of inputs, including clinical notes, vital signs, lab results, and medication history, to identify risks that may not be immediately apparent. Some tools are also being used to predict how much time a patient may have left [8], especially in serious illness, which we refer to as prognostication [6]. AI systems have been shown to be pretty accurate at identifying patients who are likely to die within 6 to 12 months. This can help guide conversations about goals of care, planning, and when to bring in palliative services, ideally earlier rather than too late.

Decision support systems powered by AI can also help with symptom control. For instance, they may suggest how to adjust opioid doses based on how the patient is doing or recommend switching to another medication if side effects start to appear. These systems work even better when combined with real-time symptom tracking from patients, such as ePROs [9] (electronic patient-reported outcomes).

However, AI is not perfect. There are genuine concerns about fairness, privacy, and whether these systems perform equally well across diverse populations with significant cultural and spiritual variations. Many AI tools are trained on data from specific regions or groups, so they may not apply everywhere. Moreover, even the best algorithm cannot replace a clinician's judgment, or the trust built between a patient and their care team. To utilize AI effectively in palliative care, a robust digital infrastructure, comprehensive staff training, and clear guidelines for data handling are essential. These factors can vary significantly between hospitals and countries, which is why implementation still has a long way to go.

Still, the direction is clear: AI has the potential to support more timely and personalized care, especially when combined with

human empathy, experience, and effective communication.

Digital Health and Remote Monitoring

Digital tools are gradually transforming the medical field, and supportive and palliative care medicine is no exception. These technologies provide patients with a way to report symptoms from home, stay connected with their healthcare teams, and receive help earlier when things start to feel off. For healthcare providers, this facility offers a window into what is happening between visits, and that is something that has always been a challenge in palliative care [10].

One of the most widely used tools is the electronic patient-reported outcome (ePRO). These are systems that enable patients to share their physical and emotional feelings through a phone, tablet, or computer. It could be pain, shortness of breath, changes in appetite, sleep disturbances, mood fluctuations, or any other factor that affects daily life. Some platforms, such as MyPal or CareVive, have already been utilized in cancer care, and there is growing evidence that they can help detect problems early, improve symptom control, and even reduce emergency visits [11].

Wearables are another area that's gaining attention. Devices like smartwatches and fitness trackers can measure various aspects, including heart rate, steps taken, sleep patterns, and activity levels. These small changes in movement or rest patterns can sometimes give early clues that a patient is getting weaker, more tired, or starting to decline. It is not perfect, but it gives extra information that might otherwise go unnoticed.

The use of telehealth, especially since the COVID-19 pandemic, has also made it easier to check in with patients more often, even when they are at home or far from the hospital. These video calls are being used for everything from symptom reviews to family meetings and challenging conversations about end-of-life care goals. Patients prefer the comfort and privacy of being in their own homes during these talks.

Of course, digital care is not always simple. Not everyone has access to a smartphone or a good internet connection. Some older patients may not feel comfortable with technology. There are also genuine concerns about privacy, data sharing, and integrating these tools into already busy clinical systems. Unless the digital tools are linked to electronic medical records and made easy to use, they risk becoming just another thing to manage.

Still, digital health can offer patients more control, better connection with their teams, and faster help when symptoms change. It does not replace face-to-face care, but it can complement it, especially when travel is difficult or time is limited, and enhances the overall patient experience.

Advances in Pharmacologic and Interventional Symptom Control

While technology and data are transforming how symptoms are tracked and predicted, there have also been important changes in the way symptoms are treated, especially for patients dealing with advanced cancer. New medications, improved delivery methods, and more targeted use of existing therapies are helping to make symptom control safer and more personalized.

Pain remains one of the most common and distressing issues in palliative medicine. Opioids are still the mainstay for moderate to severe pain, but newer options and strategies are helping fine-tune their use [13]. Rapid-onset formulations like sublingual or nasal fentanyl can offer faster relief during sudden pain spikes, often called breakthrough cancer pain [14]. These are easier to take and act more quickly, which can make a big difference in day-to-day comfort. Opioid rotation switching from one type to another happens especially when side effects or poor response limit effectiveness. Some clinicians are even using genetic testing (such as checking CYP2D6 metabolism) to guide choices and doses more precisely, although this is not yet standard practice everywhere.

In cases where pain originates from a specific area and does not respond well to medication alone, interventional procedures may be helpful. Nerve blocks, epidurals, or even neurolytic techniques (like a celiac plexus block for pancreatic cancer) can sometimes offer relief that pills simply cannot. These techniques are not suitable for everyone, but when used carefully, they can significantly enhance the quality of life.

Breathlessness, especially in patients with lung or mediastinal tumors, can be frightening and challenging to treat. Low-dose opioids like oral morphine have been shown to reduce the feeling of air hunger. Anxiolytics, such as low-dose lorazepam, are sometimes added for the emotional side of breathlessness, though they must be used with caution. Simple tools, such as a handheld fan or cool air across the face, may seem basic, but they are surprisingly helpful for many patients. In more severe cases, non-invasive ventilation or even light sedation may ease suffering.

Cachexia, or cancer-related weight and muscle loss, continues to be a significant challenge. Traditional appetite stimulants like megestrol acetate can offer some benefit, but they carry risks, especially blood clots. There is growing interest in alternatives like cannabinoids (with mixed results), ghrelin mimetics, and GDF-15 [16] blockers, though most are still in research. Currently, the most effective approach appears to be a combination of a balanced diet, effective inflammation management, regular physical activity, and emotional support.

Other symptoms like severe depression, agitation, or sedation from medications are also being managed in newer ways. Low-dose ketamine has shown promise for rapid relief of depression in select patients. Medications like dexmedetomidine or haloperidol can be used in tailored ways to treat terminal agitation or delirium [15]. Moreover, psychostimulants like methylphenidate are sometimes helpful for patients who are extremely fatigued or overly sedated by opioids. All these treatments require thoughtful use. What works for one patient may not work for another. The key is to stay updated, follow closely, and continually adopt new approaches.

Health Equity, Implementation Challenges, and Global Perspectives

While the tools of precision medicine, such as biomarkers, AI, and digital health, are opening exciting new doors in supportive and palliative care, they are not equally available to everyone. One of the biggest challenges right now is ensuring that these advances benefit not only a small group of patients in well-funded, high-tech hospitals. Many parts of the world, including some

areas within wealthier countries, still struggle with basic access to palliative care, let alone high-end innovations.

In high-income countries, there is growing use of electronic health records, real-time monitoring, and even AI systems that support clinical decisions. However, in low- and middle-income countries, the story is different. Lack of infrastructure, limited training, unreliable internet, and budget constraints make it very hard to implement these tools consistently [12]. Even when interest and willingness are present, the systems to support precision care often are not yet in place.

To use these tools in real-world practice, several things are needed:

A. Strong electronic health record systems that can link with apps, devices, and monitoring platforms

B. Clear guidelines on data privacy, consent, and how AI is used in care decisions.

C. Training for clinicians and nurses not just on how to use the tools, but how to explain them to patients

D. Systems that enable services like telehealth, digital monitoring, or genetic testing

An additional concern is that many of the models and tools currently available were developed and tested in specific populations, primarily in Western settings. They may not always work the same way in other cultural or clinical contexts. Language differences, technological access, and even how people perceive illness, and care can impact the effectiveness of a tool or its adoption. Workforce shortages are another hurdle. Even in large cancer centers, there is often a shortage of staff trained in both palliative care and digital health. In smaller or rural areas, the gaps are even bigger. Building local capacity through education, mentoring, and national policy will be crucial if these approaches are to reach a broader patient base.

Some promising examples are already emerging. The Serious Illness Care Program (SICP) at Dana-Farber, for instance, combines communication tools, ePRO systems, and AI-based risk prediction to guide care conversations. Other centers, such as MD Anderson and Memorial Sloan Kettering, are also testing innovative systems that trigger palliative care referrals, track symptoms using wearables [11], or recommend tailored interventions based on real-time data.

Still, these are mostly happening in well-resourced environments. The next step is to figure out how to adapt, simplify, and scale these tools so they can work in more places for more people. Precision care has considerable potential, but only if it is made accessible, affordable, and acceptable to the people who need it most.

Future Directions in Precision Supportive and Palliative Care

Looking ahead, it is clear that supportive and palliative care is entering a new chapter, one shaped by data, technology, and a deeper understanding of the biology behind symptoms. However, at its core, the goal remains the same: to alleviate suffering, enhance comfort, and support patients and their families during serious illness. One of the significant shifts to come is the use of more detailed biological information, not just single biomarkers, but whole patterns from various aspects, including genetics, proteins metabolism, and even gut bacteria (microbiome). This type of data could help explain why specific symptoms, such as fatigue, poor appetite, or pain, occur more frequently in some individuals than others, and which treatments are likely to be effective. It is still early, but the idea is to eventually match the proper care to the right person at the right time.

Artificial intelligence will likely play a larger role as well. Instead of just predicting problems, future AI systems could help create "smart" care plans that adapt over time based on a patient's progress and treatment outcomes. For example, if someone's symptoms start to get worse, the system might suggest a dose adjustment, a home visit, or even a conversation about future planning. These types of adaptive care pathways could reduce unnecessary treatments, improve quality of life, and better align care with patient values. Care will also become more blended. That means combining in-person visits with telehealth, remote monitoring, and home-based care. For patients who live far from hospitals or feel more comfortable at home, this approach could make a significant difference. Wearables, symptom-reporting apps, and virtual check-ins may soon be part of everyday care, not just during emergencies or pandemics.

Another important area is supporting healthcare workers, not just specialists, but also general doctors, nurses, and community health workers. In many places, there are not enough trained palliative care providers. AI and digital platforms can help fill some of these gaps by offering guidance, checklists, or decision aids, enabling teams to provide thoughtful care even without an expert at the bedside. Of course, none of this works without trust, fairness, and protection. Patients need to understand how their data is used, and tools must be tested in diverse populations, not just in large urban centers. Equity must be part of every step. Otherwise, the risk is that precision care becomes a luxury when it should be part of basic good care. The road ahead will require teamwork across disciplines, across borders, and systems. However, with the right approach, the future of palliative care could be both more personal and more precise than ever before.

Conclusion

Supportive and palliative medicine as a specialty is undergoing a paradigm shift from a primarily reactive model to a more proactive, personalized, and connected approach. Precision tools, such as biomarkers, artificial intelligence, and digital health technologies, are enabling clinicians to detect patterns earlier, respond more effectively, and align care more closely with patients' values. However, the heart of palliative care remains in honoring what matters most to each patient. Technology should enhance, not replace, the human connection at the core of this field.

However, while these innovations are rapidly advancing in high-resource settings, vast disparities persist. Many countries still lack access to even the most basic palliative care services. The rapid evolution of precision tools must therefore serve as a catalyst not just for innovation but for systemic investment and policy action to ensure that foundational palliative care is universally available. These advances should prompt health systems globally to prioritize the integration of essential palliative services, ensuring that no patient is left behind due to geographical,

infrastructural, or economic barriers [17].

Ultimately, precision care must be inclusive care. The goal is not only to treat disease with more accuracy, but to care for people with greater compassion, equity, and dignity wherever they are in the world.

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References

1. Bower JE. Cancer-related fatigue mechanisms, risk factors, and treatments. Nat Rev Clin Oncol. 2014 Oct;11(10):597-609.
2. Wang XS, Woodruff JF. Cancer-related and treatment-related fatigue. Gynecol Oncol. 2015;136(3):446-452.
3. Klepstad P, Fladvad T, Skorpen F, Bjordal K, Kaasa S, Caraceni A, et al. Influence of the OPRM1A118G polymorphism on opioid use in cancer pain management. Pain. 2008;136(1-2):232-239.
4. Argilés JM, Busquets S, López-Soriano FJ. Anti-inflammatory therapies in cancer cachexia. Eur J Pharmacol. 2011;668(Suppl 1): S81–S86.
5. Neefjes ECW, van der Vorst MJDL, Blauwhoff-Buskermolen S, Verheul HMW. Aiming for a better understanding and management of cancer-related fatigue. Oncologist. 2013;18(10):1135–1143.
6. Hui D, Paiva CE, Del Fabbro E, Steer C, Naberhuis J, van de Wetering M, et al. Prognostication in palliative care: a systematic review. Palliat Med. 2019;33(6):865-883.
7. Avati A, Jung K, Harman S, Downing L, Ng A, Shah NH. Improving palliative care with deep learning. BMC Med Inform Decis Mak. 2018;18(Suppl 4):122.
8. Elfiky A, Pany M, Parikh R, Obermeyer Z. A machine learning approach to predicting short-term mortality risk in patients starting chemotherapy. NPJ Digit Med. 2018; 1:27.
9. Basch E, Deal AM, Kris MG, Scher HI, Hudis CA, Sabbatini P, et al. Symptom monitoring with patient-reported outcomes during routine cancer treatment: a randomized controlled trial. J Clin Oncol. 2016;34(6):557-565.
10. Absolom K, Warrington L, Hudson E, et al. Phase III randomized controlled trial of eRAPID: eHealth intervention during chemotherapy. J Clin Oncol. 2021;39(7):734-747.
11. Fjell M, LeBlanc TW, Zafar SY, Kamal AH. Remote symptom monitoring and its impact on patients with advanced cancer: a narrative review. Support Care Cancer. 2022;30(9):7359–7369.
12. Oldenmenger WH, Sillevis Smitt PAE, van Dooren S, Stoter G, van der Rijt CCD. A systematic review on barriers hindering adequate cancer pain management and interventions to reduce them. J Pain Symptom Manage. 2009;34(4):394-406.
13. Smith TJ, Temin S, Alesi ER, Abernethy AP, Balboni TA, Basch EM, et al. Integration of palliative care into standard oncology care: American Society of Clinical Oncology clinical practice guideline update. J Clin Oncol. 2012;30(8):880–887.
14. Fallon M, Giusti R, Aielli F, Hoskin P, Rolke R, Sharma M, et al. Management of cancer pain in adult patients: ESMO clinical practice guidelines. Ann Oncol. 2018;29(Suppl 4):iv166–iv191.
15. Davis MP, Walsh D, Nelson KA. Palliative sedation in the management of refractory symptoms. J Support Oncol. 2003;1(3):181–186.
16. Fearon K, Arends J, Baracos V. Understanding the mechanisms and treatment options in cancer cachexia. Nat Rev Clin Oncol. 2013 Feb;10(2):90–99.
17. Worldwide Hospice Palliative Care Alliance, World Health Organization. Global Atlas of Palliative Care (2nd ed.). Geneva: WHO; 2020.

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