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AI-based prognostic risk stratification and hope in osteosarcoma and bone metastatic cancer

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Abstract: Artificial intelligence based prognostic risk stratification is increasingly applied in osteosarcoma and bone metastatic cancer to generate individualized estimates of survival, recurrence, treatment response, and complication risk. While these technologies promise greater precision in oncologic decision making, their implications extend beyond biomedical prediction into the psychosocial domain. Prognostic information is not a neutral technical output but a psychologically salient event that shapes patients' understanding of illness, emotional adjustment, communication with clinicians, and future oriented meaning making. This narrative review examines AI driven prognostic risk stratification through a psycho oncology lens, with particular attention to its relationship with patient hope. Drawing on literature from oncology, artificial intelligence, communication science, and psycho oncology, hope is conceptualized as a dynamic and adaptive process rather than simple optimism about survival. The review explores how AI based prognostic information may clarify or intensify uncertainty, influence doctor patient communication, and contribute to the construction or recalibration of hope across the disease trajectory. Ethical and psychological challenges are addressed, including risks of algorithmic determinism, inequity, emotional burden, and cultural misalignment. Clinical practice implications are outlined, emphasizing the central role of psycho oncology in mediating AI supported prognostic discussions, screening for distress, and supporting adaptive hope. By integrating technological innovation with psychosocial theory and clinical insight, this review highlights pathways toward ethically responsible and patient centered use of artificial intelligence in bone oncology that supports both informed decision making and psychological wellbeing.

Keywords: artificial intelligence; bone metastatic cancer; hope; osteosarcoma; prognosis; psycho oncology

1. Introduction

Osteosarcoma and bone metastatic cancer impose a substantial clinical and psychosocial burden, often necessitating complex, multimodal management and prolonged adaptation to functional change, even as their epidemiology and biology diverge. In the oncology literature, artificial intelligence (AI)-driven prognostic risk stratification is increasingly pursued to synthesize diverse data streams and generate individualized estimates of survival, recurrence risk, treatment response, and complication probability, with bone oncology representing a notable domain for these approaches given the high stakes of skeletal involvement and metastatic disease [1,2]. At the same time, methodological innovations in natural language processing (NLP) and machine learning (ML) are enabling the extraction of prognostic signals from unstructured data sources, including radiology reports, pathology narratives, and electronic health records (EHRs) thereby expanding the evidentiary base available for

risk assessment and decision support in oncology [3,4]. Together, these developments indicate a convergent trend in which AI-enabled prognosis is increasingly positioned to inform not only biomedical risk estimates but also the downstream psychosocial implications of prognostic information for patients confronted with bone-related malignancies [5,6].

1.1. Prognostic uncertainty, survival variability, and psychological distress

A defining feature of cancer prognosis, including osteosarcoma and bone metastases, is substantial uncertainty about individual trajectories, which can vary widely even among patients with seemingly similar clinical profiles and treatment plans. AI-enabled prognostic models, by integrating radiographic, histopathologic, molecular, and clinical data, are being developed to reduce some of this uncertainty and to provide more granular, patient-specific risk estimates; illustrative work in oncology demonstrates how computational prognostics can inform survival and progression predictions in solid tumors, including lung cancer as a prominent case study [1]. Additionally, related NLP-driven analyses of unstructured data have demonstrated feasibility in extracting prognostic signals from diverse clinical narratives [3]. The need for rigorous reporting of AI-based prognostic models has spurred methodological guidelines such as the TRIPOD-AI and PROBAST-AI frameworks, which aim to improve transparency, bias assessment, and replicability in AI-driven diagnostic and prognostic studies [5], while umbrella syntheses emphasize the role of NLP and clinical decision support systems (CDSS) in supporting risk stratification across medical domains [2]. The psychosocial burden accompanying prognostic uncertainty including distress and coping challenges has been conceptualized in terms of how patients understand, interpret, and respond to prognostic information, a process that is increasingly recognized as intertwined with the quality and framing of communication and with patients' functioning as documented in clinical narratives [6,7]. In this context, AI-enabled prognosis is not merely a biomedical estimate but a psychosocial event whose impact depends on how information is conveyed and understood by patients, families, and clinicians [5,6].

1.2. Emergence of artificial intelligence in oncologic prognosis

The emergence of AI as a prognostic tool in oncology is driven by the ability to fuse heterogeneous data types from imaging phenotypes and pathology to molecular profiles and real-world clinical records to generate individualized risk assessments and to quantify probabilities of outcomes such as survival, recurrence, response to therapy, and complications. In bone oncology and metastasis research, NLP and ML techniques are being applied to quantify disease burden and track prognostic indicators from radiology reports and other free-text sources, illustrating practical pathways by which AI can augment prognostic information available to clinicians and patients [4,8]. The rapid evolution of NLP and large language models (LLMs) has further expanded capabilities for extracting structured insights from unstructured clinical text, enabling entity recognition, relation extraction, and high-level summarization that can support prognostic reasoning and clinician–patient communication [9]. Meta-syntheses and

reviews of AI in medicine emphasize the diversity of data modalities (radiology, pathology, EHRs, multi-omics) leveraged for prognosis and the increasing role of AI-enabled decision support in routine oncology care and multidisciplinary planning [2]. The practical implications of this shift include improved extraction of prognostic signals from narrative notes and radiology reports, which has implications for both research and real-world decision-making in bone oncologic settings [8].

1.3. Prognosis as a psychosocial, not only biomedical, issue; conceptual link to hope

Although AI-driven prognosis centers on quantitative risk estimates, the information generated and communicated within the clinical encounter carries deep psychosocial meaning, shaping patients' sense of control, coping strategies, and expectations for outcomes. The psychosocial dimension of prognosis is reflected in how unstructured clinical text can be transformed into meaningful information about functioning and disability through NLP, enabling a more comprehensive picture of patient experience that extends beyond survival probability to everyday life and participation [6,7]. In parallel, systematic work on NLP in medicine and clinical decision support highlights how AI-derived prognostic information interacts with clinician judgment, patient preferences, and communication strategies, ultimately influencing psychological adjustment and shared decision-making [2,5]. From a methodological standpoint, the integration of AI prognostic tools with established reporting standards and bias assessment via TRIPOD-AI and PROBAST-AI emphasizes ensuring that prognostic estimates are delivered in ethically responsible and clinically interpretable ways that support, rather than undermine, patient well-being [5]. By framing prognosis as an integrative process that combines biomedical risk with psychosocial context accessible through structured and unstructured data this narrative review seeks to illuminate how AI-based prognostic information may influence patients' illness understanding, psychological adjustment, doctor–patient communication, and the construction of hopeful yet realistic expectations [5,6].

1.4. Aim and scope of the narrative review

Against this backdrop, the present narrative review aims to examine AI-driven prognostic risk stratification in osteosarcoma and bone metastatic cancer from a psycho-oncological perspective, focusing on how AI-derived prognostic information may shape patients' understanding of their illness, psychological adjustment, and doctor–patient communication, as well as how it may influence the development and maintenance of adaptive, realistic forms of hope. Rather than evaluating algorithmic performance alone, the review seeks to synthesize AI applications with psychosocial theory and clinical insight to guide patient-centered, ethically informed use of AI in oncology. In doing so, the work draws on methodological guidelines for AI prognostic reporting [5], the expanding literature on NLP and CDSS in oncology [2], and the broader evidence base on prognosis communication and patient functioning as captured in NLP-enabled health records research [6,7].

2. Conceptual framework: Prognostic risk stratification and hope

2.1. Prognosis as a psychosocial event

In oncology, prognosis transcends a purely biomedical forecast and operates as a consequential psychosocial event for patients and their families. Prognostic disclosure can function as a psychological stressor, eliciting emotional responses such as fear, sadness, anger, or shock, while simultaneously triggering processes of meaning-making about identity, relationships, and future plans [10,11]. The manner in which prognostic information is conveyed and interpreted profoundly influences psychological outcomes; unfavorable or uncertain prognoses are associated with heightened anxiety, depressive symptoms, fear of progression, and existential distress, whereas prognosis also modulates coping strategies and future orientation, with individuals variably responding through information seeking, goal recalibration, avoidance, or emotional withdrawal [10,11]. These dynamics underscore prognosis as a psychosocial stimulus that interacts with personal coping styles, social support, and cultural context rather than as a static biomedical fact, thereby shaping everyday functioning and life planning in meaningful ways [11].

The communicative context surrounding prognosis its framing, transparency, and alignment with patient values further modulates psychological adjustment. Research across oncology and related fields demonstrates that the quality of prognostic communication can either alleviate or exacerbate distress, influence perspectives on treatment choices, and affect the perceived legitimacy and relevance of prognostic information for patients and families [12,13]. In this regard, clinical conversations around prognosis are inseparable from psychosocial care: they are opportunities to support coping, preserve a sense of agency, and facilitate adaptive meaning-making in the face of uncertainty, rather than merely delivering numerical risk estimates [13]. Taken together, these dynamics position prognosis as a biopsychosocial process embedded in communication, social context, and patient psychology as much as in biology [10,14].

2.2. Hope in psycho-oncology

Within psycho-oncology, hope is recognized as a central, adaptive resource that supports psychological adjustment across the cancer trajectory. Conceptually, hope encompasses both a state momentary expectation regarding future outcomes and a process involving ongoing cognitive and emotional work to maintain meaning, purpose, and goals under conditions of uncertainty. Distinctions are commonly drawn between realistic hope, grounded in achievable outcomes, and existential hope, which may persist even when curative possibilities are limited and emphasize dignity, connection, or transcendence [11,15]. Empirical work across cancer populations shows that higher levels of hope are associated with better quality of life, lower psychological distress, and more adaptive coping, and that hope can bolster treatment engagement, symptom management, and perseverance in the face of burdensome therapies [15]. Importantly, hope does not equate to denial or uncritical optimism; rather, it is a dynamic, recalibrated construct that can evolve with changing clinical circumstances and patient priorities, calling for psychosocial care that supports

adaptive transformation of hope in alignment with patient values and lived realities [16].

In advanced disease contexts, hope plays a pivotal role in end-of-life adjustment, contributing to acceptance, resilience, and meaningful closure even when prognosis is limited. This emphasizes that psychosocial care should aim to sustain adaptive forms of hope such as focus on symptom control, functional preservation, autonomy, meaningful relationships, or psychosocial meaning rather than aiming to preserve an illusion of cure. Interventions that cultivate coping resources, religious or spiritual resources, social support, and open communication about goals and values can reinforce constructive hope while acknowledging uncertainty, thereby supporting overall well-being [17,18]. Consequently, clinical practice should distinguish between supportive communication that preserves agency and meaning versus strategies that enforce denial, ensuring that hope remains responsive to evolving clinical realities and patient preferences [16].

2.3. Integrating AI into the hope–prognosis relationship

The advent of artificial intelligence (AI) in prognostic risk stratification introduces a novel dimension to the prognosis–hope dynamic. AI-based models can generate personalized, probabilistic estimates by integrating heterogeneous data streams (imaging, pathology, molecular profiles, and real-world clinical information), potentially reducing uncertainty through more granular risk stratification. In bone oncology and metastasis settings, AI-enabled prognostic tools and related natural language processing (NLP) approaches are increasingly explored to estimate survival, recurrence risk, treatment response, and complication probabilities, thereby expanding the evidentiary basis available to clinicians and patients for shared decision-making [1,8]. At the same time, AI outputs can reshape patients’ experiences of uncertainty: for some, AI-driven stratification may clarify trajectories and support planning; for others, algorithmic predictions may intensify distress if perceived as deterministic or immutable. Crucially, AI does not eliminate uncertainty; it reframes it in probabilistic terms, necessitating careful contextualization within clinical conversations and patient meaning-making processes. When appropriately framed, AI-based prognosis can support adaptive recalibration of hope by shifting emphasis from survival alone toward realistic, patient-centered goals such as symptom control, functional independence, and preserved quality of life, aligned with individual values and life projects [1,5]. Without thoughtful communication and ethical governance, AI-derived prognostic information risks constraining patient agency or undermining genuine shared decision-making [5].

To responsibly integrate AI into prognosis and hope, the field emphasizes governance and reporting standards that ensure transparency and bias assessment in AI-based prediction models (for example, TRIPOD-AI and PROBAST-AI), rigorous methodological evaluation, and clear guidance for clinical implementation and patient communication. Such frameworks aim to promote interpretable, patient-centered use of AI in oncology settings, enabling clinicians to translate probabilistic prognostic information into meaningful conversations and decision-making that preserve agency and support adaptive hope [5]. The integration also benefits from advances in NLP

and clinical decision support systems that facilitate the extraction and presentation of prognostic information from unstructured data, enabling clinicians to deliver nuanced prognostic messages in ways that support coping, shared decision-making, and hopeful prospects framed within patients' goals and values [2,8]. Together, these developments advocate a psycho-oncologically informed, ethically grounded deployment of AI prognostic tools that respects patients' psychological needs, supports adaptive coping, and nurtures hope as a dynamic, responsive resource throughout the cancer journey [15].

References to the AI–hope–prognosis nexus also underscore the necessity of aligning technological innovation with psycho-oncological principles. Effective prognostic communication in AI-enabled care should be accompanied by supportive psychosocial interventions, including problem-solving approaches, coping skills training, and caregiver or family involvement, to sustain adaptive hope and meaningful engagement with care. Empirical work on psychosocial interventions in oncology and palliative contexts supports such models, highlighting those strategies like problem-solving therapy, resilience-building, and social support can bolster quality of life and attenuate distress when prognosis information is complex or emotionally salient [18]. In sum, AI-driven prognostic risk stratification has the potential to enhance patient understanding and planning, but its benefits for hope and adaptation depend on integration within ethically informed, patient-centered communication that honors individual values, coping styles, and social contexts [1].

Figure 1 illustrates a conceptual framework describing how artificial intelligence based prognostic risk stratification may influence patient hope in osteosarcoma and bone metastatic cancer. AI based prognostic information, derived from imaging, pathology, and clinical data, is first interpreted and communicated by clinicians. This information then undergoes psychosocial processing by patients, including prognostic understanding, emotional response, and meaning making. Through this process, patients construct and recalibrate hope, which may take survival related, quality of life oriented, or existential and relational forms, ultimately shaping psychological and clinical outcomes such as distress, engagement with care, and patient agency.

The bidirectional arrows surrounding the hope construction and recalibration component indicate an iterative process. Hope is continuously shaped by patients' psychosocial processing of prognostic information, while existing forms of hope simultaneously influence how subsequent prognostic information is emotionally and cognitively interpreted. This dynamic interaction emphasizes that hope is not a fixed outcome of prognostic disclosure, but an ongoing and adaptive process that evolves over time as clinical circumstances and prognostic understanding change.

3. Overview of AI-driven prognostic risk stratification in bone cancers

Artificial intelligence (AI)–driven prognostic risk stratification in bone cancers has emerged as a modality to synthesize heterogeneous data and generate individualized estimates of prognosis, including metastasis risk and survival probabilities. In osteosarcoma and in the setting of bone metastases, this line of work emphasizes clinical relevance and interpretive context over purely technical

performance, aligning AI outputs with the needs of patient-centered decision-making and psychosocial considerations [19,20]. Across these studies, AI tools typically integrate multimodal data streams imaging features from radiographs or tomography, quantitative pathology signals, and curated clinical variables to construct composite risk profiles that aim to inform discussions about prognosis and care planning while acknowledging the probabilistic nature of predictions [20,21]. Moreover, increasingly, prognostic models incorporate molecular and transcriptomic signatures, such as RNA-based prognostic markers, to enhance risk stratification and to reflect tumor biology beyond conventional clinicopathologic parameters [22,23]. In line with efforts to translate AI into routine care, several investigations stress the importance of model interpretability and transparent reporting to support clinician understanding and shared decision making, thereby facilitating the integration of AI-based risk estimates into patient consultations and care pathways [19,20].

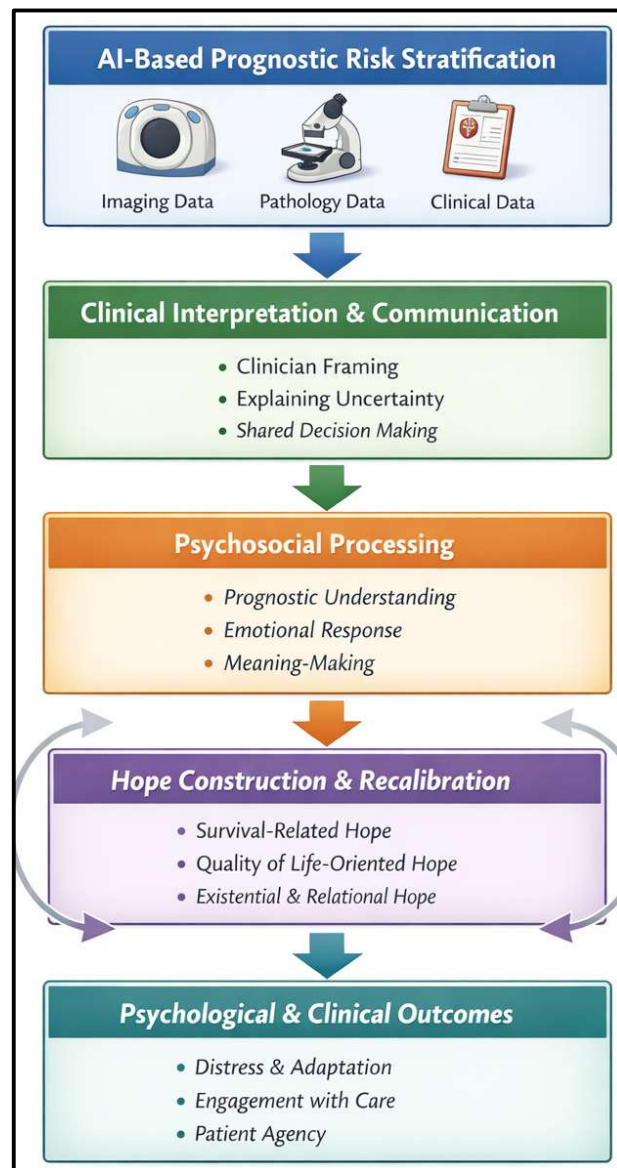


Figure 1. Conceptual framework linking AI based prognostic risk stratification and patient hope in osteosarcoma and bone metastatic cancer.

3.1. AI Applications in osteosarcoma prognosis

In osteosarcoma, AI-based prognostic models have been developed to address pronounced inter-patient heterogeneity in outcomes despite similar disease features. These models seek to forecast endpoints such as overall survival, event-free survival, recurrence risk, and response to chemotherapy, enhancing individualized prognostic conversations and tailoring treatment planning. Methodologically, AI approaches in this domain commonly fuse imaging-derived features with histopathologic insights and key clinical variables (e.g., tumor stage, location, neoadjuvant response) to yield composite risk scores or survival predictions that extend beyond conventional statistics [19,21]. Notably, interpretable machine learning frameworks have demonstrated utility in predicting distant metastasis, offering prognostic signals that clinicians can examine and contextualize within a patient's broader clinical narrative [20]. Demonstrations employing large registries and machine-learning classifiers further illustrate how AI-driven models can achieve clinically meaningful discrimination of risk and function as decision-support tools that inform discussions about prognosis and treatment choices, including potential implications for long-term functional outcomes [19]. Recent RNA-based prognostic signatures, such as immune-related multigene scores and RNA-binding protein panels, have also shown promise in refining survival and metastasis risk estimates, underscoring the expanding repertoire of AI-augmented biomarkers that can augment imaging- and clinicopathology-driven prognostication in osteosarcoma [22,23]. Collectively, these advancements reflect a trend toward AI-enabled, patient-centered prognostication that contextualizes risk within the patient's unique biology and clinical course, while emphasizing the probabilistic and modifiable nature of prognostic information [24].

3.2. AI applications in bone metastatic cancer

For bone metastatic cancer, AI-driven risk stratification has broadened to encompass outcomes beyond survival, including skeletal-related events, functional decline, pain progression, and treatment-related complications. The prognostic landscape in metastasis-prone bone diseases benefits from longitudinal clinical data, serial imaging, and treatment histories, enabling models to characterize disease trajectory and modulate decisions about surgical intervention, radiotherapy, systemic therapy, or palliative care referral. In this context, AI tools are increasingly positioned as components of clinical decision support systems that illuminate non-obvious risk patterns and support clinicians in aligning management with patient goals and expected quality of life. Although many concrete osteosarcoma-focused AI studies anchor the discussion, the underlying principle combining multimodal data to project trajectories and inform complex care decisions translates to metastatic bone disease by highlighting both survival and morbidity-related endpoints as targets for prognosis and planning [19,22]. Importantly, the emotional and practical implications of prognostic information at the level of function and morbidity are recognized in AI-driven work, reminding us that outputs must be framed within a patient-centered narrative that considers how risk estimates shape expectations and coping over time [19,22]. As with primary tumors, there is a growing emphasis on developing interpretable, transparent models and robust reporting practices to ensure that AI-

supported prognostic estimates for bone metastases are clinically meaningful and ethically integrated into care pathways [20,21].

3.3. From prediction to clinical meaning

A central translational challenge across osteosarcoma and bone metastases is converting algorithmic predictions into information with tangible clinical and psychosocial meaning. Risk scores and probabilistic estimates are most useful when embedded within patient-relevant narratives that clarify uncertainty, articulate conditionality, and connect prognostic implications to concrete treatment aims and daily functioning. Interpretable AI approaches and explicit communication about what predictions mean for individual patients are essential to render AI outputs workable in clinical encounters and in shared decision-making processes, rather than serving as abstract numerical descriptions. The potential for AI-derived prognostic information to inform patient goals such as function preservation, symptom control, and quality of life depends on how clinicians contextualize the results within the patient's values, preferences, and social circumstances, as well as how well AI tools are integrated with existing care teams and decision-support workflows [20,21]. Simultaneously, recognition of the limits of predictions namely, the incompleteness of models to capture all biological complexity and psychosocial variability reinforces the view of AI as a supportive tool that augments, but does not replace, clinical judgment, nuanced patient communication, and comprehensive psycho-oncologic care [19,20]. Together, these considerations underscore that the value of AI-driven prognostic stratification in bone cancers lies not merely in predictive accuracy but in the careful translation of risk information into ethically sound, patient-centered care that preserves autonomy, informs planning, and supports adaptive hope within each patient's lived reality.

4. Psychosocial implications of AI-based prognostic stratification

4.1. Understanding prognosis in the AI era

Artificial intelligence (AI)-driven prognostic information introduces a distinct epistemic modality into patient understanding of illness, characterized by its data-driven, probabilistic nature and its perceived objectivity relative to traditional clinician-led prognostication. This perceived objectivity can foster trust in the information, particularly among patients who value technological precision or who have encountered inconsistencies in messaging across care transitions [25,26]. Yet AI-based outputs also pose challenges for comprehension: probabilistic estimates require interpretation in light of the patient's health literacy, emotional readiness, and personal goals, limiting straightforward translation into day-to-day expectations or concrete decisions without careful framing and explanation [27,28]. Moreover, although AI can enhance the granularity of risk stratification, the outputs remain probabilistic and contingent, demanding explicit communication that conveys conditionality rather than determinism and aligns with patients' values and life projects [29]. In this context, the integration of AI-based prognosis with psycho-oncological care becomes essential: algorithmic outputs should be accompanied by patient-centered education, supportive counseling, and opportunities for meaning-making that accommodate evolving

preferences and coping strategies [26,30].

4.2. Doctor–patient communication

Effective communication in the AI era requires clinicians to position AI prognostic outputs as tools that augment not replace human judgment and empathetic dialogue. The responsibility for clear explanation rests with the clinical team: clinicians must translate AI-derived risk estimates into accessible language, acknowledge uncertainties, and explicitly discuss the implications for treatment goals and daily functioning concerning the patient’s values [25,26]. When used thoughtfully, AI-enabled prognostic frameworks can facilitate more transparent shared decision-making by offering a structured scaffold for conversations about options, trade-offs, and personal priorities, while ensuring that patients retain agency and active participation in care planning [31]. However, simply presenting AI results without critical interpretation or context risks diminishing patient engagement and may convey a sense of impersonality in decision-making. Consequently, framing AI outputs within a broader narrative of care, ongoing support, and patient-specific goals is essential to preserve therapeutic alliance and support adaptive coping in the face of uncertainty [25,26]. In pediatric and young-adult populations, where family dynamics and developmental considerations shape communication, AI-enhanced prognostic discussions must be particularly attuned to caregiver involvement, developmental stage, and the patient’s evolving autonomy, as highlighted in reviews of precision medicine and pediatric oncology communication strategies [26,30].

4.3. Hope construction and reconstruction

Hope remains a central psychosocial resource in the AI-enabled prognostic era, but its construction requires a careful balance between realism and personal meaning. AI-based risk stratification can shift hope toward patient-centered, attainable goals such as symptom control, functional preservation, relational continuity, and meaning-making rather than an exclusive focus on survival. When prognostic information is framed transparently and delivered within a compassionate care context, high-risk AI predictions can catalyze adaptive forms of hope that are congruent with the patient’s values and life context [27]. Conversely, there is a risk that AI outputs framed as definitive predictions or deterministic trajectories may threaten patient agency and promote maladaptive forms of distress if not embedded in flexible, future-oriented planning. Therefore, clinicians should foster hopeful recalibration by linking probabilistic risk to actionable goals, reinforcing ongoing support, and validating patient perspectives on what constitutes a meaningful life with illness. This approach aligns with psycho-oncological principles that endorse problem-solving and resilience-building strategies to sustain adaptation in the face of prognostic uncertainty [26]. The integration of AI into prognosis thus carries ethical and clinical imperatives: to use prognostic information to empower patients and families, support equitable access to psychosocial resources, and ensure that hope remains responsive to evolving clinical realities and personal values. New prognostic signatures and AI-driven risk tools such as gene-based or molecular signatures provide opportunities for nuanced risk communication, but their psychosocial impact depends on thoughtful translation

into patient narratives and shared decision-making, as demonstrated in recent osteosarcoma prognostic research and pediatric oncology communications literature [25–27,32]. To synthesize these psychosocial implications and clarify the role of psycho oncology in AI supported prognostic care, **Table 1** summarizes key domains influenced by AI based prognostic risk stratification and corresponding clinical considerations.

Table 1. Psychosocial implications of AI based prognostic risk stratification in bone oncology.

Domain	AI based prognostic input	Psychosocial implication	Role of psycho oncology
Prognostic understanding	Individualized risk estimates	Improved clarity or increased anxiety depending on framing	Support comprehension and manage uncertainty
Emotional response	High or low risk stratification	Fear, relief, distress, or emotional overload	Screen for distress and provide emotional support
Doctor patient communication	Algorithm supported prognosis	Perceived authority or determinism	Facilitate shared decision making
Hope construction	Probabilistic future outlook	Recalibration of hope beyond survival	Support adaptive and realistic hope
Patient agency	Risk informed care planning	Empowerment or loss of control	Reinforce patient values and choices

5. Ethical and psychological challenges

5.1. Risk of algorithmic determinism and prognostic fatalism

The deployment of AI-based prognostic stratification introduces a distinct risk that patients may interpret prognostic outputs as fixed, deterministic predictions rather than conditional probabilities, potentially leading to prognostic fatalism and a reduction in perceived personal agency. This dynamic carries clear ethical implications; fatalistic interpretations can diminish motivation to pursue treatment or supportive care and may undermine engagement with shared decision-making processes crucial to psycho-oncological care [33,34]. To mitigate these risks, clinicians should emphasize the probabilistic nature of AI-derived estimates, framing outputs within a broader clinical context and aligning with individual patient goals. This approach preserves a sense of possibility and active participation in care planning. The ethical use of AI relies on transparent communication that contextualizes uncertainty, aligns with patient values, and facilitates ongoing adjustment of goals in response to evolving circumstances, as supported by governance and governance-focused scholarship on trustworthy AI [33–35]. Furthermore, guidelines advocating for transparent reporting and methodological rigor such as AI-specific extensions to established prediction model reporting frameworks underscore the importance of conveying not only results but also limitations, uncertainties, and the conditionality of predictions within real-world care pathways [36]. Collectively, these perspectives advocate for an integrated approach where AI-derived prognostic information is embedded in psycho-oncological dialogues that uphold patient agency, enhance adaptive meaning-making, and avoid deterministic framing of outcomes [35,36].

5.2. Equity, transparency, and explainability

Equity considerations are central to the ethical use of AI in prognosis, as model

performance and outputs can reflect biases in training data, potentially exacerbating disparities related to age, ethnicity, socioeconomic status, or access to care. Without deliberate attention to representation and fairness, AI-driven risk estimates may reinforce existing inequities in cancer prognostics and care planning [37,38]. Transparency and explainability are closely linked to trust and patient engagement; both patients and clinicians benefit from comprehensible outputs that reconcile with clinical narratives and patient goals. Ethically responsible implementation demands explicit acknowledgment of model limitations, visible articulation of uncertainty, and the integration of algorithmic information with clinician judgment and patient values. This stance is supported by broader ethics and governance discussions around trustworthy AI in medicine [34,35]. Reporting guidelines and standard-setting initiatives such as AI-specific extensions to prediction model reporting (e.g., TRIPOD-AI/PROBAST-AI) provide mechanisms to enhance transparency, reproducibility, and equity in AI-enabled prognostication [36,39]. Concurrently, ongoing discourse on fairness metrics and bias assessment emphasizes the necessity for critically evaluating how AI outputs are generated and communicated within diverse patient populations, ensuring that prognostic information supports equitable access to care [37,38].

5.3. Emotional burden on patients and clinicians

The introduction of AI-generated prognostic information can impose additional emotional burdens on both patients and clinicians. For patients, algorithmic outputs may evoke heightened fear, anxiety, or distress when faced with high-risk probabilities or abrupt prognosis changes, particularly if presented without adequate context or supportive framing [40]. For clinicians, articulating AI-derived risk estimates while balancing honesty, empathy, and patient values can lead to moral distress and emotional strain, especially when predictive outputs conflict with their clinical judgment or patient preferences. Integrating psychosocial care is essential to cushion these effects, with psychosocial professionals assisting in communication strategies, coping skill development, and caregiver support to maintain adaptive functioning in the face of prognostic uncertainty [41,42]. Optimal practice should involve training clinicians in AI-aware communication, utilizing structured decision-support tools, and ensuring access to psycho-oncology resources that address both patient and clinician wellbeing as AI tools become more integrated into routine care [41,42].

5.4. Cultural considerations in interpreting AI-based prognosis

Cultural context plays a significant role in how prognostic information is perceived, interpreted, and acted upon. Beliefs surrounding illness, technology, fate, and authority influence patients' receptivity to AI-derived risk estimates and preferences regarding information disclosure. In varying cultural contexts, algorithmic predictions might be accepted as objective truth, while in others, they may elicit skepticism or discomfort, affecting trust, hope, and decision-making processes. Thus, integrating cultural sensitivity into AI-enabled prognostication necessitates exploring patients' beliefs about prognosis, technology, and care goals, and adapting communication strategies accordingly to support culturally congruent meaning-making and coping. This ethical imperative aligns with broader scholarship on justice,

health equity, and cross-cultural psycho-oncology, highlighting the importance of tailoring psychosocial care and communication to diverse populations to prevent harm and enhance wellbeing [38,40]. The literature emphasizes the need for training and organizational support for facilitating culturally informed discussions about prognosis in AI-enabled care pathways [38,40].

5.5. Governance, reporting standards, and training for ethical AI in prognosis

Robust governance and transparent reporting are foundational to the ethical application of AI in prognostic care. Adherence to AI-specific reporting and bias assessment guidelines such as TRIPOD-AI, PROBAST-AI, and DECIDE-AI facilitates clearer communication regarding methods, uncertainty, and applicability, enabling clinicians to deliver ethically responsible, patient-centered prognostic information [5,36,43]. Contemporary scholarship highlights the need for explainability and governance frameworks that address data quality, bias mitigation, and accountability within AI-enabled clinical workflows, aligning with broader considerations of trustworthy AI in healthcare [33–35]. Practical implementation requires not merely technical validation but also education and training for clinicians and psycho-oncology teams, ensuring the integration of AI-derived insights with patient narratives, shared decision-making, and supportive interventions that foster adaptive hope instead of deterministic expectations [36,39]. Together, these governance and training imperatives aim to ensure that AI-enhanced prognosis strengthens autonomy, equity, and psychosocial wellbeing in oncology and beyond.

6. Clinical practice implications for psycho-oncology

6.1. Engaging with AI-derived prognostic information

Psycho-oncology teams have a pivotal role in mediating the clinical and psychological impact of AI-derived prognostic information, reframing AI outputs as informational scaffolds rather than definitive forecasts, and ensuring that interpretation occurs within the patient's emotional, social, and existential context. By engaging early in the prognostic discussion, psycho-oncology professionals can anticipate patients' psychological responses, tailor disclosure to individual needs, and support gradual, iterative conversations about uncertainty, goals, and values. This collaborative stance aligns with broader calls for ethical, patient-centered AI deployment in oncology and reflects the importance of integrating psychosocial expertise with AI-enabled prognostication to preserve agency and meaning in care planning [44–46]. Moreover, the integration of AI-derived prognostic considerations with psychosocial care supports shared decision-making and helps translate probabilistic risk into patient-relevant narratives that resonate with daily life, functioning, and personal priorities [44,45].

6.2. Screening for distress triggered by prognostic disclosure

The disclosure of AI-based prognostic information can act as a trigger for psychological distress, necessitating systematic distress screening as a routine

component of AI-supported oncology care. Psycho-oncology teams are well-positioned to implement structured, longitudinal screening processes that monitor emotional responses to prognostic updates, recognizing that distress trajectories may evolve with new information and during transitions in care. Evidence from psycho-oncology scholarship emphasizes that early identification of distress enables timely intervention and can prevent escalation that might undermine treatment engagement or quality of life; this imperative is amplified in AI-informed prognostic dialogues where probabilistic information requires careful contextualization and supportive framing [47,48]. Integrating validated distress measures and ensuring rapid access to psychosocial interventions can thus mitigate emotional burden while supporting continued patient participation in care decisions and goal setting [47].

6.3. Integrating psychological support into AI-supported oncology care

Effective AI-supported oncology care requires intentional, pathway-spanning integration of psychological support rather than ad hoc referrals. Prognostic information generated by AI may influence choices across the care continuum from initial treatment planning to palliative or supportive care transitions making it essential that psychosocial care be embedded at multiple touchpoints. Psycho-oncology interventions can assist patients in processing prognostic information, articulating personal goals, and recalibrating hope toward adaptive, patient-centered aims such as symptom control, functional preservation, and meaningful social connections. This approach is consistent with the broader literature on integrating mental health supports into cancer care and underscores the importance of routine psychosocial care as part of AI-enabled decision-making processes in oncology [47,49]. Training clinicians and care teams to offer compassionate, transparent communication about uncertainty and to collaborate with psycho-oncology specialists can enhance resilience, reduce stigma around seeking support, and promote a holistic sense of wellbeing alongside clinical management [45].

6.4. Training needs for clinicians

The successful deployment of AI-based prognostic tools in oncology hinges on clinician training that extends beyond technical interpretation to include communication proficiency, ethical reasoning, and emotional attunement. Clinicians require education on explaining probabilistic AI outputs, conveying uncertainty, addressing emotional reactions, and supporting adaptive hope without offering false reassurance or deterministic messaging. Interdisciplinary training that brings oncologists, psycho-oncology professionals, and allied health staff together can foster shared understandings, reduce cognitive biases toward technology, and standardize compassionate communication practices during prognostic discussions. Such training is supported by contemporary scholarship on AI in oncology, highlighting the need for multidisciplinary collaboration, transparency about algorithmic limitations, and integration of AI insights with patient narratives and preferences to sustain patient autonomy and psychosocial wellbeing [50,51].

7. Future directions and research agenda

The rapid adoption of AI-based prognostic tools in oncology creates important opportunities and challenges for psycho-oncology. This section outlines three focal areas to guide future work: (1) empirical studies that examine how AI-informed prognosis influences patient hope over time; (2) the development of hope-sensitive prognostic communication models; and (3) interdisciplinary collaboration among AI developers, oncologists, and psycho-oncology professionals to ensure ethically sound and patient-centered implementation.

7.1. Empirical studies on AI-based prognosis and patient hope

A principal gap in the current literature is the lack of empirical work directly assessing how AI-derived prognostic information affects patient hope longitudinally. While AI-based risk stratification is increasingly studied from technical and clinical standpoints, its psychological consequences remain largely inferred rather than measured. Future research should prioritize longitudinal, patient-reported outcomes that track hope, distress, and meaning-making before and after AI-informed prognostic discussions. Such studies can illuminate how hope evolves as prognostic estimates are updated and reframed, as suggested by broader investigations into prognostic communication and patient coping in oncology [52–54]. Moreover, it will be critical to examine how patients differentiate AI-supported prognosis from clinician-delivered prognosis, and whether algorithmic involvement alters perceptions of certainty, control, and trust. This line of inquiry aligns with calls for ethically grounded AI deployment in oncology and the need to translate probabilistic AI outputs into patient-centered narratives that preserve agency and adaptive hope [55]. Additionally, researchers should consider cultural and developmental differences in how hope functions within AI-mediated prognostic conversations, echoing literature on prognosis communication across diverse populations and settings [56]. Together, these empirical efforts would provide an essential evidence base to guide ethically informed, psychologically attuned implementation of AI-driven prognosis in oncologic care.

7.2. Development of hope-sensitive prognostic communication models

A complementary direction involves designing and testing communication models that explicitly integrate hope into AI-supported prognostic discussions. Existing oncology communication frameworks have been developed primarily around clinician judgment and traditional prognostication; thus, they may not fully capture the unique dynamics introduced by algorithmic risk information. Hope-sensitive models should guide clinicians in framing AI-based prognostic outputs to sustain adaptability while maintaining honesty and transparency. This includes strategies for explaining uncertainty, conveying conditional probabilities, and aligning prognostic information with patients' values and life goals. Models should also anticipate responses when AI predictions conflict with patient expectations or with clinician intuition, providing structured approaches to manage cognitive and emotional dissonance. Empirical evaluation of these models is essential, and training interventions derived from them could be incorporated into psycho-oncology

education to promote consistent, patient-centered use of AI-driven prognosis across care settings [53,54,57]. In parallel, integrating contemporary governance norms such as transparent communication about model limitations and uncertainty into these models will support ethically responsible practice and shared decision-making, resonating with established guidance on prognosis communication and patient-centered care [57].

7.3. Interdisciplinary collaboration between AI developers, oncologists, and psycho-oncologists

Realizing the patient-centric promise of AI-based prognostication requires sustained interdisciplinary collaboration. AI developers, oncologists, and psycho-oncology professionals bring complementary expertise that must converge to ensure that prognostic tools are interpretable, communicable, and sensitive to psychological impact. This collaboration should begin early in AI development, including model conceptualization, output design, and implementation planning, to ensure that AI outputs are patient-friendly and compatible with psychosocial care pathways. Such cross-disciplinary engagement supports ethical governance and clinical policy development for AI-based prognosis, balancing accuracy, transparency, and psychological wellbeing. Furthermore, collaboration with psycho-oncology can help tailor AI-enabled prognostic information presentation, decision-support interfaces, and training programs to promote autonomy and adaptive hope in diverse patient populations. The literature on AI in oncology underscores the value of multidisciplinary teamwork, transparency about algorithmic limitations, and alignment of AI insights with patient narratives and preferences to sustain patient-centered care [58].

8. Conclusion

Artificial intelligence driven prognostic risk stratification is increasingly shaping clinical decision making in osteosarcoma and bone metastatic cancer. While these technologies offer new opportunities for personalized prognosis and more precise risk assessment, their influence extends beyond biomedical outcomes. Prognostic information generated through AI enters deeply personal and psychologically charged spaces, affecting how patients understand their illness, engage with care, and envision their future.

This narrative review has highlighted that prognosis should be understood as both a clinical and psychosocial phenomenon. In this context, hope emerges as a central construct through which patients interpret and live with prognostic information. Hope is not synonymous with unrealistic optimism, nor is it negated by poor prognosis. Rather, it represents a flexible and adaptive orientation toward the future that can be supported or constrained by how prognostic risk is communicated and contextualized. AI based prognostic stratification therefore functions not only as a predictive tool, but also as an indirect psychological intervention that shapes meaning making and emotional adjustment.

The integration of AI into oncology care underscores the importance of psycho-oncology expertise. Without careful framing, algorithmic predictions risk fostering

determinism, emotional distress, or erosion of patient agency. When embedded within compassionate communication, interdisciplinary collaboration, and ongoing psychological support, AI based prognosis has the potential to enhance shared decision making and support adaptive forms of hope.

Ultimately, the ethical and effective use of artificial intelligence in bone oncology depends on recognizing that technological precision must be accompanied by psychological sensitivity. Positioning hope at the center of AI supported prognostic care offers a pathway toward more humane, patient centered oncology practice that honors both scientific advancement and the lived experience of patients.

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