World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

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Harnessing Bayesian networks in cancer management: A perspective

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World Journal of Advanced Research and Reviews, 2025, 26(02), 109-114

Publication history: Received on 23 March 2025; revised on 28 April 2025; accepted on 01 May 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.26.2.1580

Abstract

Machine learning is breaking into medicine and healthcare supporting the prognosis, diagnosis and treatment selection for a wide variety of malignancies. Bayesian Networks, a sub element of Machine Learning, has potency to support clinicians and oncologists in cancer management. In this article, we discussed aspects and potential of Bayesian Networks in cancer therapeutics and this perspective is informative for medical doctors as well as bio-informaticians, AI engineers, and data analysts.

Keywords: Bayesian Networks; Cancer therapeutics; Prognosis; Diagnosis

1. Introduction

Although cancer in one of the most fatal diseases for mankind, there have been significant changes in the last decade including the cancer diagnosis, prognosis and therapy optimization. There has been a considerable investigation on cancer diagnosis by developing computational models for efficient detection of cancerous conditions [1,2]. Many bioinformaticians have adopted Artificial Intelligence (AI)-based learning approaches in cancer therapeutics [3]. Bayesian Networks (BNs) can be applied in three different categories of image-based tasks in oncology: detection, characterization and monitoring of tumors [4].

Some challenges do remain as medical data cannot be used as direct input [5]. It is crucial to extract, quantify and evaluate features. Another challenge could lie in the fact that AI will experience low exposure and expert clinicians which leads to blind spots to rare conditions as well as a repertoire of doctors experiences in disease interpretations [6].

AI-based tools can play a role in monitoring the tumor. The traditional way of confronting the tumor consists of the response evaluation criteria in solid tumors (RESICT) and the world health organization (WHO) criteria for estimating tumor burden and determining treatment response [7-9]. These methods are heavily criticized for oversimplifying complex tumor geometry and being unable to determine the efficiency of chemotherapy in the case of numerous lesions. [7-9].

A cardinal number of studies of the nexus BNs and cancer management delineate the *status quo* [10-15]; it has been alluded that AI can extract and quantify key image information by simulating complex human functions. It is recommended the elaboration of an extensive study to evaluate the extent of the current applications and segregate the research information that reveals pinnacles and tradeoffs of AI implementation in cancer management. This perspective

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discusses aspects and potential of BNs in cancer therapeutics and is informative for medical doctors as well as bio-informaticians, AI engineers, and data analysts.

2. Realising the value of Bayesian Networks

Bayesian Networks (BNs) use complex modelling approaches to manage large datasets to aid physicians in cancer management [16]. BNs is considered a powerful tool for medical doctors and specifically oncologists in clinical diagnosis and decision-making [16,17].

In cancer research AI-based tools are commonly used in imaging techniques including: computed tomography (CT) scam, magnetic resonance imaging, mammography and ultrasound [18,19]. These techniques generate vast amount of data and AI-based tools allow the translation of the datasets.

ML-based tools can recognize information that cannot be noticed by the human eye and can be used to reduce errors of omission in observation oversight. It can be used to highlight zones of interest aiding the expert in detection [20,21]. Using parameters ML-based tools can also be used to characterize the stage of the tumor. Cancer diagnostics is plagued by interrater bias and inconsistent reproducibility even among experts [21]. Using automated segmentation AI has the potential to increase efficiency, reproducibility and quality of tumor assessment. Bayesian Networks aids the clinicians with the selection of cancer treatment techniques with high level of uncertainty. BNs [22].

The advent of Machine Learning has improved malignancy treatment as the BNs can be used as prognostic and diagnostic tool for several types of malignancies [23]. The essence of BNs lifecycle in computational medical therapeutics is provided in Figure 1. Data vigilance as it is described in European Database on Cancers aims to ensure and improve patients' safety.

ML tools manufacturers for healthcare operations are ideating BNs as an efficient solution for probabilistic inference that can aid decision making in clinical operations. BN is considered as a nascent machine learning technique, inasmuch orientating to other ML techniques like artificial neural network or support vector machines, that may result in a clear and healthy healthcare arena [23,24].

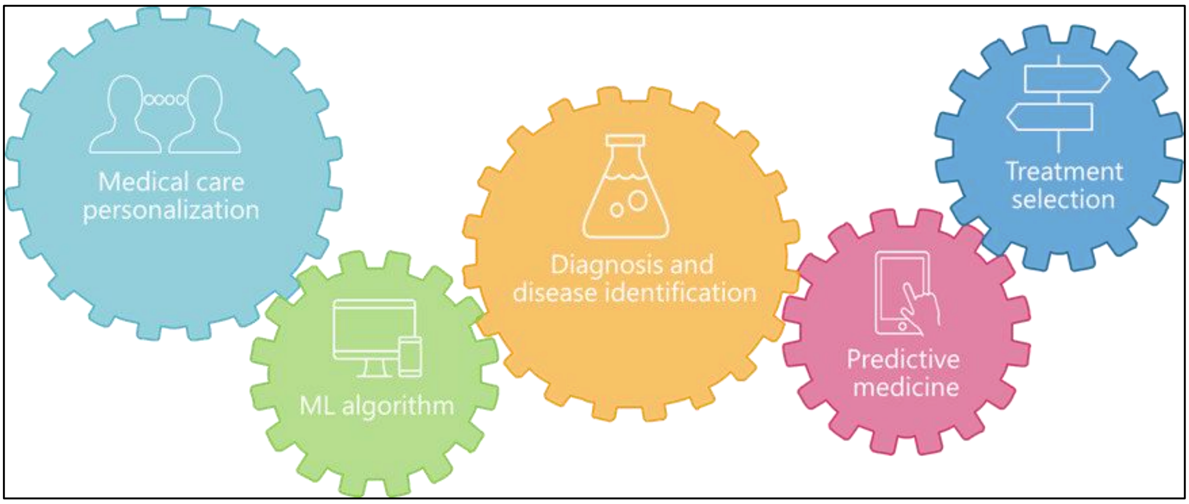

Figure 1 The evolving scheme in computational medicine concept is embodied by five pillars

Application of BNs is alluring due to the capability of assessing interdependencies of clinical factors that exist in large medical datasets [25,26]. Barriers have been identified during the adoption and applicability of BNs in cancer management. Among these constraints, the lack of unified protocols for processing heterogeneous medical data represents a significant challenge to the large-scale implementation of these technologies [27,28].

However, initiatives, such as the European "Smart4Health" project, demonstrate that harmonizing clinical databases can substantially improve the performance of BNs, achieving predictive diagnostic accuracy exceeding 90% [29]. Furthermore, the combination of BNs with explainable AI (XAI) techniques and federated learning is opening new possibilities in precision oncology [30]. Particularly in managing complex cancers, this synergy not only enhances diagnostic accuracy but also provides interpretable explanations for clinical decisions [31]. A recent multicenter study showed that hybrid systems combining BNs and deep neural networks can reduce false positives in early lung cancer detection by 32% compared to traditional methods [32].

3. Questioning the value of clinical presentation

The yawning gap amidst visual examination and invasive fine needle aspiration calls into question whether the routine decision making can underpin the drive for efficient cancer management. The attempt for treatment solutions is more than necessary for a radical veer to a successful cure with a group of features such as size, capsular or local tissue invasion being intrinsic [33].

The therapeutics deadlock redounds a cross-cutting disquiet for effective surgical applications [34]. The clustering of surgical intervention is the sine qua non for the efficient cancer treatment. The appeal of surgical resection ramps up the efficacy of carcinoma cure [34]. A quintessence surgical aiming to redeem quality in malignancy management.

Maneuverability of the carcinoma therapies circumvents conventional treatment and is a crucial component to expedite the application of advanced technologies in cancer care [35]. Against that backdrop, there is room for manoeuvre and doctors are enamored with non-invasive treatments. Medical concerns for an abrupt curtailment of adjuvant or palliative therapies is an existential risk for the patients [33]. The cure treatment management concept manifests an evolving scheme that is embodied by technological advancements [35].

The pathological deadlock redounds a cross-cutting disquiet for a proactive stance with drastic alterations in the clinical judgment. Future ventures for preoperative biopsy may be taken into account to assess the recurrent disease when evaluating a patient with a known diagnosis of cancer. The resection with negative margins resuscitated the cancer treatment and rekindled the ailing cure management.

The operative management of carcinomas hinged on the preoperative clinical suspicion or intraoperative identification of malignancy [34]. *En bloc* resection of all adjacent tissues without capsular disruption evinces the shrewdness of the surgical approach to embed to achieve grossly and microscopically negative margins, including resection of any adjacent fibroadipose or muscular soft tissue.

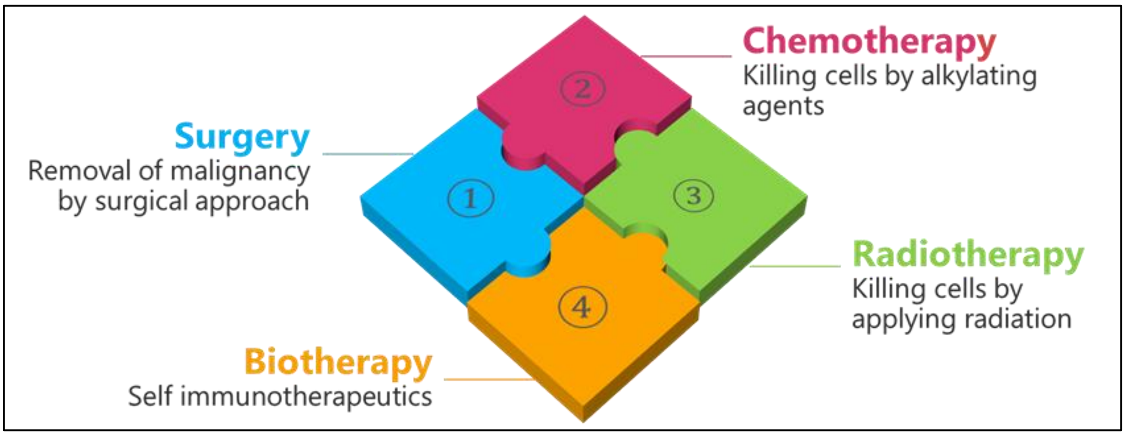

Figure 2 Traditional cancer treatment modalities

The reputation of chemotherapeutic agents is ebbing away forasmuch as tis removal attenuates the survival for patients with carcinomas. Unequivocal and plausible use of intraoperative hormone assay is crucial and may will fall into the normal range if there has been adequate resection of hormonally active disease. This may aggravate metastasis, and further exploration may have morbid repercussions in surgical treatment. Genetic and molecular analysis are bounden in order to perk up the diagnosis landscape and provide a cushion of carcinoma management.

It has been extensively alluded that chemotherapy is not sufficiently effective for the treatment of some malignancies [36]. Lack of clinical data regarding the evaluation of systemic therapy may herald the dubiousness amongst case reports. Technological breakthroughs in novel therapeutic systemic therapy, referred to by some as the critical juncture of the pharmacotherapy in the future, have led to the pledge that scientists will expand the ambit of medicines for mono therapies or combination therapies and may balk the used of non-responsive medicines [36,37].The adjuvant chemotherapy's attempts to keep pace continue to flounder due to limited data and, dubious applicability.

Researchers focus on identifying and trialing efficient chemotherapy as a treatment alternative as there radiation therapy is not standardized for several malignancies. Contentious arguments over the adjuvant radiation concomitantly jeopardize the therapy performance.

Continuing research efforts buoy the adjuvant therapy to manage the ebbs and flows of biotherapy or immunotherapy. Immunotherapy instantiates an auspicious denouement to attenuate the effects of other treatment methods. Erratic decision making due to limited data is holding back biotherapy from its potential succour to eliminate carcinoma and amortize biotherapy pitfalls.

Plausible experience is needed to dodge medical risks and decisions with synergy and alacrity amidst littoral treatment team may be taken on an individualized basis. Looking to a later levy, leveraging new therapies renders a sparking change to a surgery-based therapeutic scheme with medical risk averseness.

3.1. Leveraging Bayesian Networks in cancer management

The perpetration of immediate prognosis is regarded a crucial impetus for the physicians to ponder carcinoma diagnosis and expediting the treatment in non-invasive sound manner. Medical strategy aiming to incorporate Machine Learning in support decision making is pivotal for the mature implementation of the BNs in cancer management [24]. Barriers, such as validity issues, necessitate the comprehension of algorithms and the standardization of BNs to improve the implementation in the clinical arena [27,28].

To address these challenges and overcome these barriers, several studies are proposing certification protocols based on standards such as ISO 13485 for AI-assisted diagnostic systems, including multicenter evaluations that measure sensitivity (>95%) and specificity (>90%) in real-world scenarios [27]. Additionally, the creation of public BN model repositories, such as CancerML [28] facilitates broader implementation.

Furthermore, successful adoption of BNs requires their adaptation to existing hospital information systems (HIS/RIS/PACS) through standardized interfaces like HL7 FHIR [38]. This approach is supported by pilot experiences conducted at leading oncology centers, which have demonstrated that such integration can reduce diagnostic time by up to 40% for solid tumors [23]. However, challenges remain in interoperability with electronic health records, where natural language processing (NLP) emerges as a key solution for extracting unstructured clinical variables to feed BN models [39].

4. Conclusions

It is recommended the elaboration of an extensive study to evaluate the extent of the current applications and segregate the research information that reveals pinnacles and tradeoffs of AI implementation in cancer management. This perspective discusses aspects and potential of BNs in cancer therapeutics and is informative for medical doctors as well as bio-informaticians, AI engineers, and data analysts.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Sufyan M, Shokat Z, Ashfaq UA. Artificial intelligence in cancer diagnosis and therapy: Current status and future perspective. Computers in Biology and Medicine. 2023; 165:107356. https://doi.org/10.1016/j.compbiomed.2023.107356

[2] Hamamoto R, et al. Application of artificial intelligence technology in oncology: Towards the establishment of precision medicine. Cancers. 2020; 12(12):3532. https://doi.org/10.3390/cancers12123532

[3] Malik P, Pathania M, Rathaur VK. Overview of artificial intelligence in medicine. Journal of family medicine and primary care. Journal of Family Medicine and Primary Care. 2019; 8(7):2328. https://doi.org/10.4103/jfmpc.jfmpc_440_19

[4] Spiegelhalter DJ, Myles JP, Jones DR, Abrams KR. An introduction to Bayesian methods in health technology assessment. BMJ. 1999; 319(7208):508-12. https://doi.org/10.1136/bmj.319.7208.508

[5] Kakhi K, Alizadehsani R, Dipu Kabir HM, Abbas Khosravi A, Nahavandi S, Acharya UR. The internet of medical things and artificial intelligence: trends, challenges, and opportunities. Biocybernetics and Biomedical Engineering. 2022; 42(3):749-71. https://doi.org/10.1016/j.bbe.2022.05.008

[6] Londhe, VY, Bhasin B. Artificial intelligence and its potential in oncology, Drug Discovery Today 2019; 24(1):228-232. https://doi.org/10.1016/j.drudis.2018.10.005

[7] Eisenhauer EA, et al. New response evaluation criteria in solid tumours: revised RECIST guideline (version 1.1). European Journal of Cancer. 2009; 45(2):228-247.https://doi.org/10.1016/j.ejca.2008.10.026

[8] Schwartz, L.H., et al. RECIST 1.1 - Standardisation and disease-specific adaptations: Perspectives from the RECIST Working Group. European Journal of Cancer. 2016; 62:138-145. https://doi.org/10.1016/j.ejca.2016.03.082

[9] Park JO, et al. Measuring response in solid tumors: comparison of RECIST and WHO response criteria. Japanese Journal of Clinical Oncology. 2003; 33:533-7. https://doi.org/10.1093/jjco/hyg093

[10] Rong G, Mendez A, Assi EB, Zhao B, Sawan M. Artificial intelligence in healthcare: review and prediction case studies. Engineering. 2020; 6(3):291-1. https://doi.org/10.1016/j.eng.2019.08.015

[11] Schettini F, Venturini S, Giuliano M, et al. (2022) Multiple Bayesian network meta-analyses to establish therapeutic algorithms for metastatic triple negative breast cancer, Cancer Treatment Reviews, 111 (102468). https://doi.org/10.1016/j.ctrv.2022.102468

[12] Huehn M, Gaebel J, Oeser A, Dietz A, Neumuth T, Wichmann G, Stoehr M. Bayesian Networks to Support Decision-Making for Immune-Checkpoint Blockade in Recurrent/Metastatic (R/M) Head and Neck Squamous Cell Carcinoma (HNSCC). Cancers (Basel). 2021; 13(23):5890. https://doi.org/10.3390/cancers13235890

[13] Sesen MB, Nicholson AE, Banares-Alcantara R, Kadir T, Brady M. Bayesian networks for clinical decision support in lung cancer care. PloS one. 2013; 8(12):e82349. https://doi.org/10.1371/journal.pone.0082349

[14] Sieswerda M, Xie S, van Rossum R, et. (2023) Identifying Confounders Using Bayesian Networks and Estimating Treatment Effect in Prostate Cancer With Observational Data. JCO Clinical Cancer Informatics. 7:e2200080. https://doi.org/10.1200/CCI.22.0008

[15] Hoshi K, Kawakami J, Kumagai M, Kasahara S, Nishimura N, Nakamura H, Sato K. An analysis of thyroid function diagnosis using Bayesian-type and SOM-type neural networks. Chemical and pharmaceutical bulletin. 2005, 53(12):1570-4. https://doi.org/10.1248/cpb.53.1570

[16] McLachlan, S., Dube K, Hitman GA, Norman E Fenton NE, Kyrimi E. Bayesian networks in healthcare: Distribution by medical condition. Artificial Intelligence in Medicine. 2020; 107:101912. https://doi.org/10.1016/j.artmed.2020.101912

[17] Arora P, Boyne D, Slater JJ, Gupta A, Brenner DR, Druzdzel MJ. Bayesian networks for risk prediction using real-world data: a tool for precision medicine. Value in Health. 2019; 22(4):439-45. https://doi.org/10.1016/j.jval.2019.01.006

[18] Zhang, B, et al. Machine Learning and AI in Cancer Prognosis, Prediction, and Treatment Selection: A Critical Approach. Journal of Multidisciplinary Healthcare. 2023; 16:1779-1791. https://doi.org/10.2147/JMDH.S410301

[19] Gupta S, Kumar Y. Cancer prognosis using artificial intelligence-based techniques. SN Computer Science. 2022; 3:1-8. https://doi.org/10.1007/s42979-021-00964-3

[20] Busnatu Ș, Niculescu AG, Bolocan A, et al. Clinical applications of artificial intelligence—An updated overview. Journal of clinical medicine. 2022; 11(8):2265. https://doi.org/10.3390/jcm11082265

[21] Seoni, S., et al. Application of uncertainty quantification to artificial intelligence in healthcare: A review of last decade (2013–2023). Computers in Biology and Medicine. 2023; 1:107441. https://doi.org/10.1016/j.compbiomed.2023.107441

[22] Kyrimi, E., McLachlan S, Dube K, et al. Bayesian Networks in Healthcare: the chasm between research enthusiasm and clinical adoption. medRxiv, 2020; 5:2020-06. https://doi.org/10.1101/2020.06.04.20122911

[23] Abdullah AA, Hassan MM, Mustafa YT. A review on Bayesian deep learning in healthcare: Applications and challenges. IEEE Access. 2022; 10:36538-62.

[24] Alshuhri MS, Al-Musawi SG, Al-Alwany AA et al. Artificial intelligence in cancer diagnosis: Opportunities and challenges, Pathology - Research and Practice. 2024; 253:154996. https://doi.org/10.1016/j.prp.2023.154996

[25] Cypko MA, Stoehr M, Oeltze-Jafra S, Dietz A, Lemke HU. A Guide for Constructing Bayesian Network Graphs of Cancer Treatment Decisions. Studies in Health Technology and Informatics. 2017; 245:1355. https://doi.org/10.3233/978-1-61499-830-3-1355

[26] van der Stap L, van Haaften MF, van Marrewijk EF, et al. The feasibility of a Bayesian network model to assess the probability of simultaneous symptoms in patients with advanced cancer. Scientific Reports. 2022; 12:22295. https://doi.org/10.1038/s41598-022-26342-4

[27] Zhou Y, Hospedales TM, Fenton N. When and where to transfer for Bayesian network parameter learning, Expert Systems with Applications. 2016; 55 (361-373). https://doi.org/10.1016/j.eswa.2016.02.011

[28] Kyrimi E, Dube K, Fenton N, et al. Bayesian networks in healthcare: What is preventing their adoption? Artificial Intelligence in Medicine 2021; 116:102079. https://doi.org/10.1016/j.artmed.2021.102079

[29] Angelopoulos N, Chatzipli A, Nangalia J, Maura F, Campbell PJ. Bayesian networks elucidate complex genomic landscapes in cancer. Communications Biology. 2022; 5:306. https://doi.org/10.1038/s42003-022-03243-w

[30] Kuipers J, Suter P, Moffa G. Efficient Sampling and Structure Learning of Bayesian Networks, Journal of Computational and Graphical Statistics, 2022; 31(3):639-650. https://doi.org/10.1080/10618600.2021.2020127

[31] Mao L, Wang H., Hu LS, Tran NL, Canoll PD, Swanson K, Li J. Knowledge-Informed Machine Learning for Cancer Diagnosis and Prognosis: A Review, IEEE Transactions on Automation Science and Engineering, vol. 22, pp. 1008–1028, 2025. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=10806835

[32] Rawat D, Sharma S, Bhadula S. "Case based Reasoning Technique in Digital Diagnostic System for Lung Cancer Detection" 2023 8th International Conference on Communication and Electronics Systems (ICCES), Coimbatore, India, 2023; 1355-1361. 10.1109/ICCES57224.2023.10192863. https://ieeexplore.ieee.org/abstract/document/10192863

[33] Liu B, Zhou H, Tan L, et al. Exploring treatment options in cancer: tumor treatment strategies. Signal Transduction and Targeted Therapy. 2024; 9:175. https://doi.org/10.1038/s41392-024-01856-7

[34] Saunders AC, Mutebi M, Rao TS. A Review of the Current State of Global Surgical Oncology and the Role of Surgeons Who Treat Cancer: Our Profession's Imperative to Act Upon a Worldwide Crisis in Evolution. Annals of Surgical Oncology. 2023; 30(6):3197-3205. https://doi.org/10.1245/s10434-023-13352-3

[35] Debela DT, Muzazu SG, Heraro KD, Ndalama MT, Mesele BW, Haile DC, Kitui SK, Manyazewal T. New approaches and procedures for cancer treatment: Current perspectives. SAGE Open Medicone. 2021; 9:20503121211034366. https://doi.org/10.1177/20503121211034366

[36] Letai A, de The H. Conventional chemotherapy: millions of cures, unresolved therapeutic index. Nature Reviews Cancer. 2025; 25:209–218. https://doi.org/10.1038/s41568-024-00778-4

[37] Tilsed CM, Fisher SA, Nowak AK, Lake RA and Lesterhuis WJ. Cancer chemotherapy: insights into cellular and tumor microenvironmental mechanisms of action. Frontiers in Oncology. 2022;12:960317. https://doi.org/10.3389/fonc.2022.960317

[38] Wong-Pérez D, Mar-Cornelio O. HL7 Interoperability Standard in Health: Systematic Review of the Literature. Revista Cubana de Informática Médica, 2023; 15. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1684-18592023000200009&lng=es&tlng=es.

[39] Hossain E, Rana R, Higgins N, Soar J, Datta Barua P. Natural Language Processing in Electronic Health Records in relation to healthcare decision-making: A systematic review. Computers in Biology and Medicine. 2023; 155:106649. https://doi.org/10.1016/j.compbiomed.2023.106649