

Advancements in oligometastatic breast cancer: a comprehensive review of current strategies and the role of artificial intelligence

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Abstract

In the dynamic landscape of Breast Cancer (BC), Oligo-Metastatic Breast Cancer (OMBC) presents unique challenges and opportunities. This comprehensive review delves into current strategies for addressing OMBC, covering locoregional and site-specific metastasis management, and addressing both surgical and minimally invasive therapies as essential components. Moreover, the transformative role of Artificial Intelligence (AI) is spotlighted.

However, while the future looks promising, several limitations need addressing, including the need for further research, especially in diverse patient populations and resource-challenged settings. AI implementation may require overcoming the lack of Electronic Health Records acceptance in resource-challenged countries, which contributes to a scarcity of large datasets for AI training. As AI continues to evolve, validation and regulatory aspects must be continually addressed for seamless integration into clinical practice.

In summary, this review outlines the evolving landscape of OMBC management, emphasizing the need for comprehensive research, global collaboration, and innovative AI solutions to enhance patient care and outcomes.

Keywords: Artificial Intelligence, Breast Neoplasms, Oligometastatic Breast Cancer, Locoregional Management, Metastasis Treatment

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Introduction

Breast Cancer (BC) is the second-most frequent

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malignancy and the second-leading cause of cancer-related death in women, respectively.¹ Globally, it is anticipated that 2,261,419 women will receive a new BC diagnosis in 2020, and 684,996 will eventually succumb to the disease.¹ BC carries an excellent prognosis in the early stage, with a 99% 5-year survival rate for locally invasive disease.² For Locally Advanced Breast Cancer (LABC) with distant metastases or Stage IV disease, the 5-year survival drops considerably to 27%.³ According to estimates, 20 to 30 percent of women with Early-stage Breast Cancer (EBC) will develop metastatic disease, and 6 to 10 percent of all women will be diagnosed with de novo Metastatic Breast Cancer (MBC),⁴ with the most prevalent locations for distant metastases being bone (41.1%), lung (22.4%), liver (7.3%), and brain (7.3%).⁴⁻⁶

MBC is defined as the presence of metastases larger than 0.2mm proven histologically to be present at distant sites, or detectable tumours, as established by conventional clinical and radiographic modalities.⁵ Oligo-Metastatic Breast Cancer (OMBC) is defined as the presence of 1-5 distant metastases in one or more organs, however, it is essential to acknowledge that considerable variability exists among subgroups within OMBC based on diverse treatment strategies, outcomes, and the timings of presentation.⁵ Although a multimodal approach and the careful selection of patients have shown promise in achieving favourable prognoses, the existing body of evidence guiding treatment recommendations for OMBC remains somewhat limited.⁵ This comprehensive review aims to delineate the current strategies encompassing both surgical and minimally invasive interventions, employed in the management of OMBC, while also shedding light on the emerging role of Artificial Intelligence (AI) in optimizing the management of this distinct clinical entity. Through exploring AI's potential applications, we aim to contribute to the evolving landscape of OMBC management, striving for improved outcomes and a deeper understanding of this complex disease paradigm.

Materials and Methods

A systematic search of the literature was conducted to

identify studies relevant to the management of Oligo-Metastatic Breast Cancer (OMBC) and the role of artificial intelligence (AI) in this context. Electronic databases, including PubMed, MEDLINE, Embase, and Google Scholar, were systematically queried for publications, from January 2010 up to the knowledge cutoff date of September 2023. The search strategy employed combinations of keywords and Medical Subject Headings (MeSH) terms such as "Oligo-Metastatic Breast Cancer," "Breast Cancer metastasis," and "AI in cancer management." Studies included in this review met specific criteria, encompassing peer-reviewed original research articles, systematic reviews, meta-analyses, and clinical trials, published in the English language. Articles that did not fulfill these criteria or were duplicates, case reports, conference abstracts, or opinion pieces were excluded. Initial screening of article titles and abstracts was conducted by two independent reviewers, followed by a full-text review of selected articles to determine inclusion. Data extracted from these studies were structured into themes concerning OMBC management, locoregional treatment, site-specific treatment modalities (e.g., liver, bone, lung, brain), and AI applications. A narrative synthesis approach was used to summarize and discuss findings, as a meta-analysis was not feasible due to the heterogeneity of the studies. This review, while informative, is subject to inherent limitations, including the potential for selection bias and the exclusion of more recent developments beyond the September 2023 knowledge cutoff date.

Results

The impact of Loco-Regional Treatment (LRT) on OMBC survival was investigated through several Randomized Controlled Trials (RCTs). These trials, conducted by Seema A Khan et al, Florian Fitzal et al, Rajendra Badwe et al, and Atilla Soran et al, aimed to analyse the effects of LRT on overall survival in OMBC patients, Table-1.^{6,7,8,9}

The results of these trials varied across the studies, with some studies showing better locoregional control without discernible differences in overall survival, while others demonstrated recruitment challenges and no significant impact on survival. Similarly, studies regarding Site-Specific Metastasis Management in OMBC were also identified and are summarised in Tables 2-4.¹⁰⁻²⁴ These studies encompass a range of interventions, such as liver resection with 30-58% 5-year survival, diverse treatments for bone metastases showing median survival of 2-3 years and a 60-70% response rate with External Beam Radiation Therapy (EBRT), and surgical approaches for brain metastases, including combined surgery and Whole Brain Radiotherapy (WBRT) for enhanced local and distant

control.^{11,12,18,19,22-24}

Artificial Intelligence is making significant strides in BC management, with systems like LYmph Node Assistant (LYNA) achieving an AUC of 99.6% and demonstrating transformative potential in detecting metastases in sentinel lymph node biopsies.²⁵ Other AI models have also shown exceptional performance in identifying metastases in primary BC patients, enhancing diagnostic accuracy when combined with other diagnostic parameters.²⁶⁻³⁰ Despite promising results in BC metastasis detection, the application of AI in OMBC remains relatively unexplored, with existing literature primarily focusing on primary breast cancer and sentinel lymph nodes. Further exploration and integration of AI-driven approaches are crucial for advancing personalized, efficient OMBC management.

Discussion

Casting Light on Loco-Regional Treatment: A Critical Component in the Oligometastatic Breast Cancer Saga

Loco-Regional Treatment (LRT) of OMBC refers to the surgical management of the local primary tumour along with a metastatic site with curative intent. The type of LRT solely depends on the stage of the disease, tumour characteristics, and patient preferences.⁵

Following the diagnosis of OMBC, the mainstay treatment of the disease remains Systemic Therapy (ST).⁵ However, recent studies have shown that LRT of the primary tumour is not only beneficial for the palliation of symptoms and prevention of cancer-related complications but has also started being reconsidered for its therapeutic purposes.² Several prospective trials are carried out to assess the role of primary surgery in OMBC with varying outcomes, mentioned below in Table 1.⁶⁻⁹

In the reported trials, however, HR-positive patients made up the bulk of the LRT arm patients, followed by those who were Her2-positive, and a significant portion had bone-only metastasis.⁷⁻⁹ The Turkish trial that demonstrated improved survival outcomes identified several key prognostic factors, including age, HR status (with better outcomes in luminal-type tumours), disease burden, and the presence of bone-only oligometastatic disease.⁹

A recently published study that assessed the part primary surgery plays in de novo OMBC had results indicating that combining LRT for the primary tumour with contemporary ST appears to yield favourable outcomes in terms of both Disease-Free Survival (DFS) and Overall Survival (OS).⁵ Present clinical guidelines recommend LRT for specific cases, primarily due to the absence of robust

Table-1: Impact of Locoregional Therapy on Survival in Oligo-Metastatic Breast Cancer: Insights from Randomized Controlled Trials.

Author Name	Study Design	Objective	Sample Size and Methods	Inclusion Criteria	Outcomes
Seema A Khan et al ⁶	Randomized Controlled Trial	Analyse the effect of locoregional therapy for the intact primary tumour on patients with MBC's overall survival.	390 participants signed up, and 256 were divided into two groups: those who planned to continue with systemic therapy or have locoregional therapy (surgery and radiation for primary site).	Four to eight months of systemic therapy without disease progression for women with MBC with an intact primary tumour.	No discernible variation in overall survival. Better locoregional control with no effect on life quality.
Florian Fitzal et al ⁷	Randomized Controlled Trial	Comparing the median survival of patients with de novo stage IV MBC who received primary systemic therapy or primary surgery followed by systemic therapy.	90 patients were randomised to receive either main systemic therapy (Arm B) or surgery followed by systemic therapy (Arm A).	Patients with stage IV BC who have never received treatment.	No discernible variation in overall survival. Trial was abandoned early because of insufficient recruitment.
Rajendra Badwe et al ⁸	Randomized Controlled Trial	Analyse the impact of locoregional treatments (surgery and radiotherapy) on patients' overall survival who initially presented with MBC.	350 patients were randomly randomised to receive locoregional therapy (LRT) or no LRT at all.	Individuals under 65 with de novo MBC who had not previously received treatment.	No proof that LRT affects survival as a whole.
Atilla Soran et al ⁹	Randomized Controlled Trial	For patients with stage IV BC who are treatment naive, compare the effects of LRT followed by systemic therapy to systemic therapy alone.	274 patients were randomly assigned to either systemic therapy (ST) or (LRT).	Stage IV BC patients that are treatment naive.	Although prolonged follow-up revealed a considerable improvement in median survival, there was no difference in 36-month survival with upfront surgery.

evidence supporting its widespread application. However, there may exist a subset of patients who stand to gain more from LRT, particularly those of a younger age, with lower tumour burden (such as those with oligometastatic or bone-only disease), and possessing a favourable molecular subtype (specifically, Hormone Receptor-positive patients). Consequently, the inclusion of LRT for the primary tumour in the comprehensive treatment plan should be a subject of discussion within a multidisciplinary framework for all patients diagnosed with de novo OMBC.

Tailored Approaches to Site-Specific Metastasis Management in Breast Cancer

Liver: Although liver metastasis develops in almost 50% of all patients with metastatic breast cancer, the liver is not the most frequent initial site of distant metastases.^{10,11} In 5% to 20% of patients, BC liver metastases are the initial site of the disease's metastatic spread. These patients have a poor prognosis of 4–8 months without treatment

and 18–24 months even with ST.¹⁰⁻¹² Treatment options for liver metastases are mentioned in Table-2.¹⁰⁻¹⁷

Bone: OMBC that spreads to the bones presents a distinct clinical profile compared to MBC originating from other primary sites, with notable differences in its clinical presentation, prognosis, and treatment strategies.¹⁸ The advent of bisphosphonates and newer medical agents has revolutionized the initial management of bone metastases, reshaping the approach to this challenging aspect of BC care.^{11,18} Bone involvement is a frequent occurrence in MBC, with the spine followed femur, and humerus being the most commonly affected sites.¹⁸ The overarching treatment goals for patients with bone metastases are multifaceted. They encompass not only the relief of pain but also the restoration and maintenance of functional capabilities. Moreover, the management of bone metastases aims to prevent the occurrence of hypercalcaemia and metabolic disturbances while safeguarding against bone marrow

Table-2: Treatment Modalities and Outcomes for Liver Metastases in Oligo-Metastatic Breast Cancer.

	Description	Indications	Survival Outcomes	Prognostic Factors	Side Effects/Toxicity
Surgical					
Hepatic resection ^{10,11,12}	In addition to general selection criteria; lesions must be liable to complete resection + presence of adequate liver remnant (>20% critical volume in normal liver, >40% if steatosis/cirrhosis)	Normal liver function and performance level, no extrahepatic metastases or controlled extrahepatic metastasis, and sufficient liver remanent after surgery.	5-year survival: 30-58% Median OS 15-63 months Recurrence rate was 42.5%	Microscopic negative margins (R0) resection, fewer liver metastases, BCLM less than 3 cm, a longer interval to the diagnosis of BCLM, hormone receptor status of primary breast cancer, HR positivity, documented response rate before pre-resection to chemotherapy/non-progressive disease	Morbidity 0-44%, postoperative mortality 0-6% Surgical complications and morbidity
Non-surgical					
Hepatic Arterial Infusion of Chemotherapy (HA1) ^{11,13}	The primary supply of tumours is the hepatic Artery (HA), while the rest of normal liver parenchyma is supplied by the Portal Vein (PV). Cytotoxic drugs mixed with iodized oil is instilled into HA.	Good residual volume, sufficient blood flow, good functional status	Median survival: 7.0-14.2 months	A longer interval to the diagnosis of BCLM, hormone receptor status of primary breast cancer, HR positivity	Major => post-chemoembolization syndrome (fever, pains, nausea, LFTs; 60-80% patients for weeks-months Adverse effects: grade 3 liver dysfunction in 5-39% 30-day mortality 0-9.5%
Trans Arterial Chemoembolization (TACE) ^{11,13,14}	The primary supply of tumours is the hepatic Artery (HA), while the rest of normal liver parenchyma is supplied by the Portal Vein (PV). Obstruct HA flow + Instillation of cytotoxic drugs mixed with iodized oil into HA, followed by embolization using gelatine sponge particles (spare normal liver)	Good residual volume, sufficient blood flow, good functional status, Lesions size & numbers	Median survival: 4.6-47 months TACE had higher response rates (34%) than chemo-infusion. (19%)	Treatment at an earlier stage, tumour burden, hormone status, baseline liver function, Documented chemo responsive/ non-progressive disease, the better response is seen when multi-modal Rx is given TACE +/- RFA, TACE +/- SBRT, TACE +Chemotherapy.	Major => post-chemoembolization syndrome (fever, pains, nausea, LFTs; 60-80% patients for weeks-months Blood toxicities (leukopenia, granulocytopenia, anaemia, and thrombocytopenia), liver toxicity, and grade 3 liver dysfunction in 5-39% 30-day mortality 0-9.5%
Radiofrequency Ablation (RFA) ^{11,15}	High-frequency alternate current transmitted via probe tip to targeted tumour	Lesions less than 3 cm, a single liver metastasis, a position away from major blood vessels, or	Median DFS: 11 months, Median OS: 32 months Local tumour progression: 11.6%,	size < 2.5cm, HR +, Her 2 negative, no extrahepatic metastases, the better	Gastrointestinal issues, rare late side effects such as ulcers and fibrosis, Radiation-

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	=> extreme heat production (>60 degrees Celsius) => coagulative necrosis killing tumour cells	a subcapsular location such as during surgery	Local recurrence: 55.1%	response seen when multi-modal Rx; RFA + CT and RFA + surgery.	Induced Liver Disease (RILD)
Stereotactic Body Radiation Therapy (SBRT) ^{11,16}	A limited number(oligo-fractionation) of high dose radiations; 10-20 Gyi in 3-5 Fractions focused on the target tumour area using markers to achieve a conformal and compact dose distribution with a controlled motion to lower normal tissue damage	Elderly non-surgical patients are favoured for less than/equal to 5 Liver metastasis with a maximum tumour size of 6 cm, location (often limited segments/single lobe), controlled or absent extra-hepatic disease, acceptable performance status, adequate hepatic volume and function post procedure.	LC rates: 70-100% at 1 year, 60-90% at 2 years, Median OS: 10-48 months	Tumour size (3-4cm), prescription dose, tumour volumes (<40 cm ³) and histology, presence of bone-only disease(concurrent), oligometastatic lesion, stable/regressing lesion before SBRT	Acute side effects: gastrointestinal issues; Rare late side effects: ulcers, bile duct stenosis, pulmonary fibrosis, renal fibrosis, RILD
Interstitial Laser Therapy (ILT) ^{11, 17}	Direct placement of laser fibres made of quartz that provide laser light to the tumour and cause hyperthermic coagulative necrosis.	5 metastases or less, none greater than 5 cm.	Median survival: 2.1-5.6 years	Small tumour volume, TACE + ILT, ILT+ CT (better results)	Complication rates <1.5% reported, can be done as an OPD procedure

Table-3: Treatment Options and Outcomes for Bone Metastases in Oligo-Metastatic Breast Cancer.

Treatment	Median Survival And Response rate	Dosing/procedure	Indication
External Beam Radiation Therapy (EBRT) ^{11,18,19}	Median survival: 2-3 years Response rates: 60-70%	8 Gyi in single Fr for uncomplicated bony metastasis 20 Gyi x 5 Fr for poor functional status patients 30 Gyi x 10 Fr for good functional status patients	Symptomatic bony lesion (multiple at single site).For pain control, prevent disease progression.
Stereotactic Body Radiation Therapy (SBRT) ^{11,18,19}	Median survival: 2-3 years Response rates: 90% response rate, Response duration of 13 months	Single 16 Gyi or Single 8 Gyi	Symptomatic bony lesions (limited number).For pain control, prevent disease progression.More common in spinal deposits.
Surgery ^{11,18,19}	Better survival rates (60% after 1 year, 36% after 2 years) Median survival: 10 months	Bone excision with prosthetic reconstruction (for early weight-bearing, less re-operation rates)Load-sharing intramedullary devices preferred over load-bearing plates and screws.	For peri-articular and joints involvement: resection (hemi or complete joint) followed by Hemi-arthroplasty or joint replacement.For long bones Intramedullary nailing is referred.

invasion, spinal cord compression, and the occurrence of pathological fractures.^{11,18} In this complex landscape of OMBC, addressing bone metastases with a comprehensive and proactive approach is pivotal for

enhancing patients' quality of life and overall outcomes. The treatment options in OMBC to bones are represented in the Table-3 below.

Table 4: Treatment Modalities and Outcomes for Brain Metastases in Oligo-Metastatic Breast Cancer.

Surgery ^{11,22,23}	Stereotactic Radiosurgery (SRS) ^{11,22,23,24}	Whole Brain Radiotherapy (WBRT) ^{11,22,23,24}
Indications: Patients with solitary brain lesion, lesions with mass effect, larger size, diagnostic specimen needed, acceptably low procedural morbidity, & stable extracranial disease.	Indications: 1-3 brain lesion, good performance status, stable extracranial disease	Indications: Multiple metastasis >4
Combined surgery followed by WBRT => better local (excision) and elsewhere brain disease control	Combined SRS followed by WBRT => better disease control locally (tumour site) and elsewhere in brain. RTOG-9508 Trial	↓ local and elsewhere brain recurrences when used as an adjunct to surgery and SRS

The spine stands out as the most frequent site for bone metastasis with median OS, typically around 10 months following surgical intervention.^{11,18,19} Several prognostic indicators influence the management approach for spinal metastases, including oestrogen receptor (ER) positivity, the specific location within the spine (e.g., cervical spine vs. other areas), the presence of multiple spinal metastatic sites, concomitant visceral metastases, the involvement of more than two spinal segments requiring intervention, and recurrent or persistent disease following radiation therapy.^{11,18,19} Spinal metastasis with pain and neurological compromise typically necessitates spinal decompressive surgery. In cases of spinal metastasis causing pain without neurological compromise, percutaneous vertebroplasty or kyphoplasty, guided by imaging, may be suitable; kyphoplasty offers better control and prevents cement extrusion, while radiofrequency ablation (RFA) combined with percutaneous stabilization is an option for cases with failed radiation therapy that do not require extensive surgery.^{11,19}

Lungs: OMBC to the lungs presents unique challenges. While it is often considered a systemic disease when lung metastasis is present, there is no robust data to support surgical resection of pulmonary tissues in cases of metastatic breast cancer.^{11,20,21} Approximately 12% of MBC cases involve the lungs, with a median survival of around 24 months.^{20,21} Studies have shown contrasting 5-year survival rates between medical management and surgery, with surgery often offering a better outcome (35% vs. 11%), with improvement in survival from 30-50%.²⁰⁻²² A meta-analysis reported an OS rate of 46% following pulmonary metastatectomy.²² Prognostic factors in these cases include a short disease-free interval (DFI) of less than 3 years, incomplete resection of metastases, larger metastatic size (>2cm), unilateral or bilateral involvement, multiple pulmonary metastases (>1), HR-negative metastasis, and the presence of pleural effusion.^{11,20-22}

Brain: Brain metastases represent a significant clinical challenge in the context of OMBC, with a median survival rate of merely 4 to 6 months.^{11,23} Early-stage Breast Cancer (EBC) carries a 5% risk of brain metastasis, which increases to 15% for LABC, and escalates further to 25% to 55% in advanced stages.^{11,23} Notably, the presence of the Her2 neu gene amplification is associated with an additional 5% risk, even after adjuvant therapy, while Triple-Negative Breast Cancer (TNBC) patients face a 5-year risk of 7.4%, compared to a minimal 0.1% risk in Luminal-A subtype, often leading to a more rapid diagnosis of brain metastasis following the initial BC diagnosis.^{11,23}

Definitive treatment options for brain metastases encompass a multidisciplinary approach. Surgical intervention may be considered in select cases, while radiation therapy, owing to the radiosensitive nature of BC metastasis, remains a mainstay.^{11,23,24} Chemotherapy, targeted therapies, and radiosensitizers tailored to target the tumour are among the evolving strategies aimed at improving outcomes for patients grappling with the formidable challenge of brain metastases in the context of MBC. Table-4 summarises the treatment options employed for MBC in the brain.

Revolutionising Oligo-Metastatic Breast Cancer Management: The Transformative Role of Artificial Intelligence

Artificial intelligence (AI) is increasingly demonstrating its transformative potential in the management of BC. With an AUC of 99.6%, AI systems like the LYmph Node Assistant (LYNA) are revolutionizing how we detect MBC in sentinel lymph node biopsies.²⁵ Similarly, another study assessed deep learning's role in BC metastasis detection, where AI-assisted pathologists outperformed both the AI and pathologists individually. Notably, AI increased sensitivity for micro-metastases in lymph nodes (91% vs. 83%) and reduced review times for these cases (61 vs. 116 seconds). Pathologists also found image classification easier with AI assistance.²⁶ Despite the promising results

demonstrated in BC metastasis detection, it's worth noting that similar AI-driven advancements for OMBC remain relatively unexplored. The existing literature primarily focuses on primary breast cancer and sentinel lymph node metastasis detection and surveillance.

More recently, a study involving 6,703 BC patients assessed the performance of AI-guided clinicomics (features extracted from high-dimensional images obtained from MRI and ultrasound) in predicting distant metastasis (bone, visceral and brain metastasis). The results showed that lymph node metastasis, and increased CA153, CEA, and CA125 levels, were all substantially related to a higher probability of distant metastasis in BC patients (p -value < 0.05). The reproductive history, lymph node metastasis, and higher levels of CA153, CEA, and CA125 were linked to an increased risk of bone metastasis on sub-group analysis (p -value < 0.05), whereas visceral metastasis were linked to lymph node metastasis, estrogen / progesterone receptor positivity, higher levels of CA153, CEA and endocrine therapy (p -value < 0.05), and brain metastasis were linked to a higher ER positivity and higher levels of CA153, CEA and CA125 levels (p -value < 0.05).²⁷ Another novel AI system (MEAI) demonstrated exceptional performance in identifying lymph nodes and distant metastases in primary BC patients, achieving an Area Under the Receiver Operator Curve (AUROC) of 0.934 on a test set. When combined with pathologists, the mixed diagnostic model significantly enhanced diagnostic accuracy, particularly for less experienced pathologists, highlighting the AI system's potential to aid in the automated detection of metastases in breast cancer.²⁸ A similar study by Nakai et al. assessed the sensitivity of AI-powered software in identifying liver metastases, particularly those missed by radiologists. The software detected liver metastases with a per-lesion sensitivity of 70.8%, including those initially missed. When used in conjunction with radiologists' clinical interpretation, it showed promise for lowering the prevalence of missed metastases while retaining a low rate of false positives.²⁹

In a different study, metastatic status in BC patients was classified using retrospective Electronic Health Record (EHR) records using an AI model. The model had high Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of 0.93 and 0.86, respectively, and an AUROC of 0.88.³⁰ It significantly outperformed business rules, offering a valuable tool to impute missing stage information in EHRs, aiding in clinical trial enrollment and outcomes studies.³⁰ Regarding EHR, another paper introduces a Case-Based Reasoning (CBR) method that enhances explainability in medical diagnosis and therapy

classification in BC using Explainable Artificial Intelligence (XAI). Unlike "black box" algorithms, CBR retrieves similar cases from a database/EHR and visually presents their similarities to the query, enabling transparent and justifiable reasoning. The proposed method, tested in BC management, exhibits comparable classification accuracy to k-Nearest Neighbours algorithms while providing better explainability.³¹ However, to make AI a working reality in BC management we need to work on large data sets to train the models to better understand and predict surgical decisions for BC patients as per the stage and disease characteristics.

Paving the Path of AI Advancements for Oligo-Metastatic Breast Cancer in Resource-Challenged Settings

The transformative role of artificial intelligence (AI) in the management of OMBC holds significant promise for healthcare systems in Low-and Middle-Income Countries (LMICs). While LMICs often face resource constraints, innovative AI-driven solutions can help bridge gaps in cancer care. AI applications in OMBC detection and management can potentially lead to more accurate and timely diagnoses, improving treatment outcomes and quality of care for patients in LMICs. AI algorithms can assist healthcare providers in optimizing treatment decisions, especially when expert oncologists are in short supply. These technologies could also aid in triaging patients, allowing healthcare facilities to allocate limited resources more efficiently. However, for AI to make a meaningful impact in LMICs, considerations regarding accessibility, affordability, and integration into existing healthcare infrastructure are paramount. Collaborative efforts between international health organizations, governments, and the private sector will be essential to ensure that AI-driven advancements benefit patients and healthcare providers in resource-constrained settings, ultimately contributing to improved cancer care and outcomes in LMICs. Also, it's high time to maintain a cancer repository at both national and international levels to gather collective data for cancer patients, to understand the clinico-pathologic characteristics of the disease and to train large data sets for both disease predictions and management.

While the literature presented offers valuable insights into the management of OMBC and the potential of AI in this context, it's important to acknowledge several limitations. First, the studies discussed are not exhaustive, and more research is needed to comprehensively understand the role of AI in OMBC, especially in the context of diverse patient populations and healthcare systems. The available studies primarily focus on metastasis detection

and treatment, leaving gaps in other aspects of patient care, such as psychosocial support and survivorship. Additionally, the applicability of AI solutions in resource-challenged settings, as highlighted, is a promising but complex endeavour, and the practical implementation of AI in LMICs may require addressing numerous logistical, infrastructure, and financial barriers. Furthermore, the low acceptance of EHRs in LMICs results in a lack of large datasets to train AI models tailored to our population. Finally, the rapidly evolving nature of AI technologies and the need for ongoing validation and regulatory considerations are essential factors to consider as AI becomes more integrated into clinical practice.

Conclusion

In conclusion, navigating the complexities of oligometastatic breast cancer demands a comprehensive approach. Current strategies, encompassing locoregional management and site-specific metastasis treatment, offer valuable insights into improving patient outcomes. Furthermore, the emerging role of artificial intelligence shows significant potential in enhancing detection, treatment decision-making, and prognostication for OMBC. As we continue to explore these avenues, inclusive research, and global collaboration, we can strive for more effective management strategies, ultimately advancing the field and improving patient care.

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Abbreviations:

BC - Breast Cancer
 EBC - Early-stage Breast Cancer
 LABC – Locally Advances Breast Cancer
 OMBC - Oligo-Metastatic Breast Cancer
 AI - Artificial Intelligence
 LRT - Loco-Regional Therapy
 MBC - Metastatic Breast Cancer
 HR - Hormone Receptor

Her2 - Human Epidermal Growth Factor Receptor 2
 LYNA - LYmph Node Assistant
 AUC - Area Under the Curve
 EHR - Electronic Health Record
 LMICs - Low-and Middle-Income Countries
 AUROC - Area Under Receiver Operator Curve
 CEA - Carcinoembryonic Antigen
 DFS - Disease-Free Survival
 OS - Overall Survival
 SBRT - Stereotactic Body Radiation Therapy
 RFA - Radiofrequency Ablation
 EBRT - External Beam Radiation Therapy
 SRS - Stereotactic Radiosurgery
 WBRT - Whole Brain Radiotherapy
 RILD - Radiation-Induced Liver Disease
 OPD - Outpatient Department
 CBR - Case-Based Reasoning
 XAI - Explainable Artificial Intelligence

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