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From Primary to Spine: A Collaborative Surgical Framework for Breast Cancer with Spinal Metastases

[1]Dr. Richa Rani, [2]Dr. Saurabh Patel

[1]MBBS, DNB (General Surgery), Fellowship in Breast Oncosurgery

Department of Breast Oncosurgery, Medanta, Patna

[2]MBBS, MS (General Surgery), DrNB Neurosurgery Trainee

Medanta, The Medicity, Gurugram

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Abstract: **Background: Breast cancer is the most common malignancy in women worldwide, and the spine is the most frequent site of skeletal metastasis, occurring in up to 70% of patients with metastatic disease. The clinical presentation is often insidious — patients may present first to a neurosurgeon with axial back pain, radiculopathy, or frank myelopathy, without any prior breast cancer diagnosis. This bidirectional clinical reality necessitates a structured collaborative framework between the breast oncosurgeon and neurosurgeon.**

Objective: This review defines the complementary and interdependent roles of the breast oncosurgeon and neurosurgeon in the detection, evaluation, surgical planning, and postoperative management of breast cancer spinal metastases. We propose an evidence-based collaborative surgical framework applicable in multidisciplinary oncology settings.

Methods: A narrative review of peer-reviewed literature published between 2000 and 2024 was conducted using PubMed, Scopus, and Web of Science databases. Search terms included "breast cancer spinal metastases," "neurosurgery breast oncology collaboration," "separation surgery," "NOMS framework," "SINS score," and "multidisciplinary spine oncology." Fifty-five relevant articles were identified and synthesized.

Results: Breast cancer spinal metastases exhibit molecularly driven heterogeneity. The Spinal Instability Neoplastic Score (SINS) and the Neurological-Oncological-Mechanical-Systemic (NOMS) framework provide evidence-based surgical thresholds. Surgical indications encompass epidural spinal cord compression, spinal instability, radioresistant disease, intractable pain, and diagnostic uncertainty. A collaborative surgical framework — incorporating structured referral criteria, multidisciplinary tumor board (MDT) protocols, systemic therapy integration, and radiation sequencing — improves time-to-surgery and neurological outcomes.

Conclusion: Breast cancer reaches beyond the breast. An integrated, protocol-driven collaboration between the breast oncosurgeon and neurosurgeon optimizes patient outcomes across all phases of metastatic spinal disease. Standardized referral pathways, shared MDT platforms, and surgical sequencing algorithms are essential to this collaboration.

Keywords: **Breast cancer; spinal metastases; collaborative framework ; multidisciplinary team; NOMS; SINS; epidural spinal cord compression.**

1. INTRODUCTION

Breast cancer is the most frequently diagnosed malignancy and a leading cause of cancer-related mortality in women globally, with an estimated 2.3 million new cases diagnosed annually [1]. Among all visceral and skeletal metastatic sites, the spine stands pre-eminent — occurring in 30–70% of patients with Stage IV breast cancer — and constitutes the most common cause of neurological disability in the oncological population [2,3].

The clinical journey of a patient with breast cancer spinal metastasis does not always begin in the breast clinic. A substantial proportion of patients present primarily to the neurosurgeon with symptoms of back pain, radiculopathy, or progressive

limb weakness — with the underlying breast malignancy undisclosed or undetected at the time of spinal evaluation [4]. This paradigm demands that the neurosurgeon possess sufficient oncological acumen to suspect, investigate, and urgently coordinate with the breast oncosurgeon, thereby reversing the conventional unidirectional referral pathway.

Conversely, the breast oncosurgeon who manages a patient with known metastatic breast cancer must recognize the "red flags" of impending spinal cord compromise and refer promptly before irreversible neurological deterioration occurs. The delay between the onset of spinal symptoms and surgical decompression is directly correlated with neurological outcomes — every hour of cord compression without intervention reduces the probability of functional recovery [5].

This review presents a structured, evidence-based collaborative surgical framework that defines the roles of both the breast oncosurgeon and neurosurgeon across the entire continuum of breast cancer spinal metastasis — from initial diagnosis to surveillance. We examine the surgical indications, decision-making tools, molecular subtype implications, systemic therapy interfaces, and multidisciplinary tumor board (MDT) models that underpin this collaboration.

2. EPIDEMIOLOGY AND PATHOPHYSIOLOGY OF BREAST CANCER SPINAL METASTASES

2.1 Incidence and Pattern of Spinal Involvement

Skeletal metastases occur in approximately 70% of women with metastatic breast cancer, with the vertebral column representing the most common site — accounting for nearly 40% of all bone metastases [6]. The thoracic spine (T4–T8) is the most frequently affected segment due to its direct vertebral venous plexus communication with the intercostal veins draining the breast, a pathway first described by Batson [7]. The lumbar spine and cervicothoracic junction are also commonly involved.

Spinal metastases arise predominantly through hematogenous dissemination via Batson's paravertebral plexus — a valveless venous network facilitating retrograde spread of circulating tumor cells into vertebral marrow. Once lodged in the vertebral body, tumor cells activate osteoclasts through RANK-L signaling, inducing osteolytic destruction that compromises vertebral structural integrity, leading to pathological fracture, kyphotic deformity, and eventual epidural extension with cord compression [8].

2.2 Molecular Subtype and Spinal Behavior

The molecular subtype of breast cancer critically determines the pattern, pace, and prognosis of spinal metastasis. Luminal A (HR+/HER2−) tumors exhibit the highest frequency of bone metastases but the most indolent behavior, often amenable to endocrine therapy modulation. HER2-enriched and triple-negative subtypes, though less frequently associated with bone-predominant disease, present with rapid, destructive vertebral involvement requiring urgent surgical intervention [9,10].

Table 1. Breast Cancer Molecular Subtypes and Their Spinal Metastasis Characteristics

Subtype	Receptor Status	Bone Mets Frequency	Spinal Behavior	Surgical Implication
Luminal A (HR+/HER2−)	ER+/PR+, HER2−, low Ki-67	Highest (~70%)	Osteolytic; slow progression	Elective timing; endocrine therapy first
Luminal B (HR+/HER2+)	ER+, HER2+, high Ki-67	High (~60–65%)	Mixed lytic/blastic; moderate pace	Consider anti-HER2 + BMA before surgery
HER2-Enriched	ER−/PR−, HER2+	Moderate (~40%)	Rapidly destructive; high cord risk	Urgent surgery if ESCC; concurrent trastuzumab
Triple-Negative (TNBC)	ER−/PR−, HER2−	Lower (~25%) but aggressive	Rapidly progressive; poor bone quality	Emergency decompression often needed; limited systemic options

BMA = Bone-Modifying Agent; ESCC = Epidural Spinal Cord Compression; TNBC = Triple-Negative Breast Cancer

3. CLINICAL PRESENTATION: WHEN THE NEUROSURGEON SEES THE PATIENT FIRST

3.1 The Neurosurgeon as the First Point of Contact

A clinically critical — and frequently underappreciated — scenario is the patient who presents to the neurosurgery clinic or emergency department with back pain, lower limb weakness, or bladder dysfunction as the presenting complaint, with no documented diagnosis of breast cancer. Studies suggest that up to 20% of patients with spinal metastases have an unknown primary malignancy at initial presentation [11]. Breast cancer accounts for the largest proportion of these "unknown primary" spinal lesions in women.

The neurosurgeon encountering such a patient must maintain a systematic oncological approach

- A careful history — any prior breast lumps or biopsies, nipple discharge, axillary swelling, or a family history of BRCA-related cancers
- Physical examination — bilateral breast examination and bilateral axillary lymph node and supraclavicular fossa assessment,
- Whole-body imaging — PET-CT or bone scintigraphy to characterise disease extent and identify additional lesions that may point to the primary
- Tumour markers — serum CA 15-3, CEA, and alkaline phosphatase, alongside a receptor panel if tissue is available
- Dedicated breast imaging — bilateral mammography and ultrasound to identify an occult primary, even when breast symptoms are absent
- Spinal biopsy — CT-guided or open, mandatory before proceeding if histological confirmation is needed and the clinical picture is uncertain

Upon identification of breast cancer as the likely primary, immediate referral to the breast oncosurgeon is imperative, even if spinal surgery is urgently indicated. This initiates the collaborative loop that defines the framework proposed in this review.

3.2 Neurological Grading and Urgency Classification

The Frankel grading system and the American Spinal Injury Association (ASIA) impairment scale are used to document baseline neurological status. The degree of epidural spinal cord compression (ESCC) is graded on MRI using the Bilsky-Laufer grading system (Grade 0–3), with Grade 2–3 indicating high-grade compression requiring urgent surgical consideration [12]. The concept of the "six-hour window" — wherein decompression within six hours of acute neurological deterioration maximises recovery — underscores the time-critical nature of the neurosurgeon's role [13].

4. SURGICAL DECISION-MAKING: THE NOMS AND SINS FRAMEWORKS

4.1 The NOMS Framework

The Neurological-Oncological-Mechanical-Systemic (NOMS) framework, introduced by Bilsky et al. at Memorial Sloan Kettering Cancer Center, provides a systematic approach to surgical decision-making in spinal metastases [14]. NOMS evaluates four independent parameters:

- Neurological: degree of cord or nerve root compression (Bilsky grade)
- Oncological: radiosensitivity of the tumor (breast cancer is radiosensitive; TNBC less so)
- Mechanical: spinal stability assessed by SINS score
- Systemic: patient's overall oncological burden and medical fitness for surgery

In breast cancer spinal metastases, the NOMS framework directs the neurosurgeon toward one of three pathways: (a) radiation alone for low-grade compression with radiosensitive disease; (b) separation surgery followed by stereotactic body radiotherapy (SBRT) for high-grade compression; or (c) en bloc resection for oligometastatic, radioresistant disease. The breast oncosurgeon's input is critical for the "Oncological" and "Systemic" arms of this assessment.

4.2 The Spinal Instability Neoplastic Score (SINS)

The SINS was developed and validated by the Spine Oncology Study Group to objectively quantify spinal instability due to metastatic disease [15]. Scores range from 0 to 18, with higher scores indicating greater instability and stronger surgical indications.

Table 2. Spinal Instability Neoplastic Score (SINS) — Components and Surgical Thresholds

Parameter	Category	Score
Location	Junctional (C0–C2, C7–T2, T11–L1, L5–S1)	3
	Mobile spine (C3–C6, L2–L4)	2
	Semi-rigid (T3–T10)	1
	Rigid (S2–S5)	0
Pain	Yes — mechanical pain or pain with movement	3
	Occasional non-mechanical pain	1
	Pain-free lesion	0
Bone lesion quality	Lytic	2
	Mixed (lytic/blastic)	1
	Blastic	0
Spinal alignment	Subluxation/translation present	4
	De novo deformity (kyphosis/scoliosis)	2
	Normal alignment	0
Vertebral body collapse	>50% collapse	3
	<50% collapse	2
	No collapse with >50% body involved	1
	None of the above	0
Posterolateral involvement	Bilateral	3
	Unilateral	1
	None	0
INTERPRETATION	0–6 Stable | 7–12 Indeterminate (surgical consultation) | 13–18 Unstable (surgery indicated)	**Max = 18**

In clinical practice, a SINS score ≥7 mandates neurosurgical referral, even in the absence of overt neurological deficit. The breast oncosurgeon should be familiar with this threshold to facilitate timely consultation.

5. INDICATIONS FOR SURGICAL INTERVENTION

Surgery in breast cancer spinal metastases is not undertaken indiscriminately. Evidence-based indications govern the neurosurgical decision and require alignment with the systemic disease context provided by the breast oncosurgeon. The landmark randomized controlled trial by Patchell et al. (2005) demonstrated that direct decompressive surgery followed by radiotherapy resulted in significantly better ambulatory outcomes than radiotherapy alone for patients with spinal cord compression [16]. This evidence supports proactive surgical evaluation in eligible patients.

Table 3. Surgical Indications and Recommended Interventions in Breast Cancer Spinal Metastases

Indication	Clinical Scenario	Recommended Surgical Intervention
Epidural Spinal Cord Compression (ESCC)	Myelopathy, paraparesis, grade 2–3 ESCC on MRI	Emergency decompressive laminectomy ± posterior stabilisation + SBRT
Spinal Instability (SINS 13–18)	Pathological fracture, vertebral collapse >50%, kyphotic deformity	Posterior pedicle screw fixation ± anterior reconstruction; kyphoplasty for single-level
Radioresistant Disease	Progressive mets despite prior radiation; TNBC subtype	Separation surgery to create epidural space for high-dose SRS (18–24 Gy)
Intractable Mechanical Pain	SINS 7–12; failed conservative measures and radiation	Percutaneous vertebroplasty or kyphoplasty; posterior stabilisation if multilevel
Diagnostic Uncertainty	Isolated spinal lesion without known primary; atypical imaging	CT-guided or open biopsy; frozen section; oncosurgical planning thereafter
Oligometastatic Disease	1–3 spinal levels; controlled primary breast cancer; good performance status	En bloc vertebrectomy (WBB-guided) with curative intent + adjuvant radiation

5.1 Epidural Spinal Cord Compression (ESCC)

High-grade ESCC (Bilsky Grade 2–3) represents the most urgent surgical indication. Circumferential epidural tumor causing cord displacement requires emergent decompressive laminectomy with or without posterior stabilisation. The dual goals are: (a) restoration of the spinal canal and (b) structural stabilisation to allow subsequent high-dose SBRT [17]. The breast oncosurgeon must be alerted immediately to hold or modify systemic therapy perioperatively.

5.2 Separation Surgery and SBRT

Separation surgery — a paradigm-shifting minimally invasive technique — achieves decompression without radical resection, creating an adequate epidural margin (>2–3 mm) around the cord to safely deliver high-dose stereotactic radiosurgery [18]. Subsequent SBRT (18–24 Gy in 1–3 fractions) addresses residual tumor biologically. For breast cancer — particularly hormone-receptor-positive subtypes — this combined approach achieves durable local control rates exceeding 85% at two years [19].

5.3 En Bloc Resection for Oligometastatic Disease

In select patients with 1–2 vertebral levels of involvement, controlled primary disease, and favorable performance status, en bloc vertebrectomy guided by the Weinstein-Boriani-Biagini (WBB) classification offers a potentially curative-intent approach. This is most applicable in HR+ oligometastatic breast cancer, where long-term survival exceeds five years in well-selected cohorts [20]. Pre-operative coordination with the breast oncosurgeon ensures optimal systemic disease control and avoids prohibitive wound-healing risks from recent chemotherapy.

6. THE COLLABORATIVE SURGICAL FRAMEWORK: DEFINING ROLES

The cornerstone of this review is the delineation of a structured, reproducible collaborative surgical framework. This framework spans seven phases of care, with clearly defined roles for each specialty.

Table 4. Phase-by-Phase Collaborative Roles of Breast Oncosurgeon and Neurosurgeon in Spinal Metastatic Breast Cancer

Phase of Care	Breast Oncosurgeon's Role	Neurosurgeon's Role
Initial Diagnosis	Primary tumor resection; staging workup; bone scan/PET-CT; initiate systemic therapy	Not yet involved unless neurological symptoms present
Spine Met Detection	Identifies spinal lesion on surveillance imaging; reviews SINS score; decides referral trigger	Receives referral; performs neurological examination; orders MRI spine with contrast

MDT Tumor Board	Provides molecular subtype, systemic therapy status, prognosis, patient performance status	Presents SINS/NOMS assessment, cord compression grade, surgical risk-benefit analysis
Pre-operative	Optimizes nutritional/haematological status; coordinates bone-modifying agent pause; anaemia correction	Surgical planning (approach, levels, implants); embolisation if hypervascular; anesthesia coordination
Surgery	Primary tumor control if simultaneously progressing; lymphedema/wound assessment	Decompression and/or stabilisation (separation surgery, en bloc, MIS, kyphoplasty)
Post-operative	Resumes systemic therapy; coordinates SBRT/SRS referral; monitors primary site	Neurological recovery assessment; rehabilitation coordination; wound surveillance
Surveillance	Regular PET-CT/bone scan; new metastasis detection; endocrine/chemotherapy adjustment	Follow-up MRI spine; implant integrity check; re-operation decision if progression

6.1 Referral Criteria: When the Breast Oncosurgeon Must Call the Neurosurgeon

Timely referral is the single most impactful act a breast oncosurgeon can perform in the management of spinal metastases. The following constitute mandatory referral triggers:

- New or progressive back pain in a patient with known breast cancer — regardless of neurological status
- Spinal lesion with SINS ≥7 on any imaging modality
- Radiological evidence of epidural extension on MRI (any Bilsky grade)
- Any neurological deficit — limb weakness, sensory loss, sphincter dysfunction
- Rapid progression of vertebral destruction on serial imaging within 4–6 weeks
- Isolated spinal lesion in new patient — biopsy decision requires neurosurgical input

6.2 The Multidisciplinary Tumor Board (MDT): The Shared Decision-Making Platform

The spine oncology MDT constitutes the operational heart of the collaborative framework. At this board, the breast oncosurgeon presents the molecular profile, receptor status, current and planned systemic therapy, and overall disease burden. The neurosurgeon presents the radiological findings, SINS/NOMS assessment, surgical options, and perioperative risk. Together, with radiation oncology, medical oncology, and palliative care, the optimal management strategy is formulated [21].

Data from dedicated spine oncology MDT programs demonstrate a significant reduction in time-to-surgery (from a median of 8.4 days to 3.1 days) and improved patient selection for surgery versus non-operative management [22]. This underscores the operational and outcome-level benefit of institutional MDT infrastructure.

6.3 Systemic Therapy and Surgical Timing

The intersection of systemic breast cancer therapy and spinal surgery timing is a critical collaborative discussion. CDK4/6 inhibitors (palbociclib, ribociclib) — increasingly used in HR+ metastatic breast cancer — carry myelosuppressive risk that elevates surgical infection and haematological complications [23]. As a rule, elective spinal surgery should be deferred until absolute neutrophil count exceeds 1,500/mm3. Bone-modifying agents (zoledronic acid, denosumab) may increase the risk of poor bone healing; the breast oncosurgeon must advise on perioperative pausing schedules, typically 4–6 weeks prior to instrumented spinal surgery [24].

Conversely, in the setting of acute ESCC requiring emergency surgery, no systemic therapy contraindication justifies delay — operative decompression must proceed regardless of cycle timing, with haematological support as needed.

7. RADIATION ONCOLOGY INTERFACE

The integration of radiation therapy into the surgical pathway is a defining feature of modern breast cancer spinal metastasis management. Conventional external beam radiation therapy (cEBRT, 30 Gy in 10 fractions) has historically been the first-line treatment for radiosensitive spinal metastases without cord compression or instability. However, the advent of stereotactic body radiotherapy (SBRT/SRS) has transformed the postoperative landscape [25].

In the combined separation surgery plus SBRT paradigm, the neurosurgeon creates the epidural margin; the radiation oncologist then precisely targets the residual circumferential tumor with tumoricidal single or hypofractionated doses. This collaboration — particularly effective in HR+ breast cancer — achieves local control rates of 80–90% at 12 months without significantly increased toxicity [26].

The breast oncosurgeon must be cognisant of radiation-induced tissue changes when planning future systemic or locoregional interventions. Radiation myelopathy, wound breakdown in irradiated fields, and vertebral osteonecrosis (particularly with denosumab co-administration) represent potential long-term complications requiring interdisciplinary surveillance [27].

8. SURGICAL OUTCOMES AND QUALITY OF LIFE

Outcome assessment in breast cancer spinal metastasis surgery must encompass neurological recovery, pain control, functional independence, and health-related quality of life (HRQoL). Breast cancer — particularly HR+ disease — is associated with the most favourable post-surgical survival among all spinal metastasis primaries, with median post-surgery survival exceeding 18–24 months in well-selected patients [28]. This survival advantage underscores the clinical and ethical imperative of aggressive surgical intervention in eligible patients.

Functional outcomes — measured by Frankel/ASIA grade improvement, Eastern Cooperative Oncology Group (ECOG) performance status, and the MD Anderson Cancer Center Symptom Inventory (MDASI) — demonstrate that 65–80% of ambulatory patients maintain ambulation following surgical decompression, and 40–60% of non-ambulatory patients regain walking ability when surgery is performed within 48 hours of cord compression [29].

Patient-reported outcomes (PROs), including the EORTC QLQ-C30 and QLQ-BM22 modules specific to bone metastasis, provide a comprehensive picture of the patient's subjective experience. Shared collection and review of PRO data by both the breast oncosurgeon and neurosurgeon is recommended at each follow-up visit to capture the dual dimensions of systemic disease burden and neurological recovery [30].

9. EMERGING FRONTIERS

9.1 Minimally Invasive Spine Surgery (MIS)

Percutaneous pedicle screw fixation, endoscopic approaches, and robotic-assisted spine surgery are increasingly applied in breast cancer spinal metastases to minimize perioperative morbidity, accelerate return to systemic therapy, and reduce blood loss. MIS techniques are particularly advantageous in frail patients receiving immunotherapy or in those with multi-level disease requiring staged procedures [31].

9.2 Liquid Biopsy and Surgical Timing

Circulating tumor DNA (ctDNA) and circulating tumor cell (CTC) assays are emerging as potential biomarkers for guiding surgical timing in metastatic breast cancer. A rising ctDNA trajectory despite systemic therapy may indicate the need for earlier surgical intervention to prevent structural compromise, while a falling trajectory may support deferral of elective spine surgery [32].

9.3 Artificial Intelligence in Surgical Planning

Machine learning models trained on radiomics features from spinal MRI datasets are demonstrating promising accuracy in predicting vertebral fracture risk, ESCC grading, and surgical outcome prediction in breast cancer spine metastases [33]. Integration of AI-assisted decision support into the MDT platform represents a future direction for optimising the collaborative surgical framework.

10. TABLES

The following figures schematically represent the collaborative pathway described in this review.

Table 1: The Bidirectional Referral Pathway: Breast Surgeon to Neurosurgeon and Vice Versa
. ***Arrow 1 (Breast to Neuro):*** *Patient with known breast cancer develops back pain / MRI shows spinal met → Referral trigger → Neurosurgery assessment.* ***Arrow 2 (Neuro to Breast)****: Patient with back pain/myelopathy presents to Neurosurgeon first → Occult breast cancer identified on workup → Urgent Breast Oncology referral. Central shared zone = MDT Tumor Board. Include: SINS score, NOMS assessment, imaging flowchart icons.]*

Table 1. *The Bidirectional Referral Pathway: Breast Surgeon to Neurosurgeon and Vice Versa*

Table 2: The NOMS Decision Algorithm Applied to Breast Cancer Spinal Metastases
[Decision tree flowchart. Start: New spinal lesion in breast cancer patient. ***Branch 1 —*** *Neurological: Grade 0-1 (no cord compression) vs Grade 2-3 (high-grade ESCC).* ***Branch 2 —*** *Oncological: Radiosensitive (HR+, Luminal) vs Radioresistant (TNBC).* ***Branch 3 —*** *Mechanical: SINS 0-6 (stable) vs 7-12 (indeterminate) vs 13-18 (unstable).* ***Branch 4 —*** *Systemic: Good performance status vs poor. Outcomes: Radiation alone / Separation surgery + SBRT / En bloc resection / Palliative care. Colour-coded by urgency: Red = Emergency (<24h), Orange = Urgent (<72h), Green = Elective.]*

Table 2. *The NOMS Decision Algorithm Applied to Breast Cancer Spinal Metastases*

Table 3: Proposed Collaborative Surgical Timeline: From Diagnosis to Surveillance
[Horizontal timeline from left (Breast Cancer Diagnosis) to right (5-year Surveillance). ***Marked phases:*** *(1) Primary Surgery [Breast Surgeon]; (2) Staging & Bone Surveillance [Breast Surgeon + Radiologist]; (3) Spine Met Detection [Both]; (4) MDT Discussion [Full MDT]; (5) Spinal Surgery [Neurosurgeon]; (6) Post-op Systemic Therapy [Breast Surgeon + Medical Oncologist]; (7) SBRT [Radiation Oncologist]; (8) Rehabilitation [Physiotherapy + Both Surgeons]; (9) Surveillance [Both]. Color-code each phase by responsible specialty. Indicate referral trigger points with vertical dotted lines and alarm icons.]*

Table 3. *Proposed Collaborative Surgical Timeline: From Diagnosis to Surveillance*

11. DISCUSSION

Breast cancer is, by its metastatic nature, a disease that transcends its organ of origin. When tumor cells traverse Batson's plexus and colonise the vertebral column, the patient enters a clinical space that no single specialty can navigate alone. The framework presented in this review is constructed on the premise that surgical excellence in this domain is inherently collaborative.

The finding that a significant proportion of patients present first to the neurosurgeon — rather than the breast oncosurgeon — with spinal cord compression from an undisclosed breast primary is both a diagnostic and a system-design challenge. It demands that spine surgeons maintain oncological vigilance as part of their standard neurological evaluation protocol. The converse — a breast oncosurgeon who fails to recognise the neurological urgency of an ESCC and delays referral — is equally consequential.

The molecular heterogeneity of breast cancer further complicates this collaboration. A patient with Luminal A disease may appropriately defer elective spine surgery for four to six weeks while initiating or optimising endocrine therapy. A patient with TNBC and high-grade cord compression has no such luxury — the neurosurgeon must operate within hours, and systemic therapy is a postoperative consideration [34].

The limitations of this review include its narrative methodology and the heterogeneity of the existing literature in terms of surgical technique, outcome measures, and follow-up duration. Prospective, multi-institutional collaborative studies — jointly designed by breast oncosurgeons and neurosurgeons — represent the highest priority for future research in this domain.

12. CONCLUSION

Breast cancer does not end at the breast. When it reaches the spine — as it does in the majority of patients with Stage IV disease — it enters a domain that demands the combined expertise of two surgical specialties. The breast oncosurgeon and neurosurgeon, working within a structured collaborative framework supported by a multidisciplinary tumor board, radiation oncology, and modern surgical technologies, can deliver coordinated, evidence-based care that preserves neurological function, maintains quality of life, and extends survival.

The bidirectional referral pathway proposed in this review — wherein the neurosurgeon encountering a new spinal lesion in a woman promptly investigates for breast primary, and the breast oncosurgeon recognising spinal instability promptly escalates to neurosurgery — is the operational cornerstone of this collaboration. Institutional adoption of structured MDT protocols, validated scoring tools (NOMS, SINS), and shared outcome monitoring will further consolidate this partnership.

Breast cancer beyond the breast demands surgery beyond the breast — and that surgery demands a framework beyond any single specialty.

DECLARATIONS

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Consent for Publication: Not applicable.

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Figure 1: Representative Histopathological Findings