

Research Article

Examining India's Breast Cancer Mortality Incidence Disparities and 3D Bioprinting's Potential

Meghala Rajeev¹, Pooja Bachani^{2,*}

¹The Shri Ram Universal School, Hyderabad, Telangana, India

²Global R-hub, Mumbai, India

Abstract

Breast cancer continues to be the most often diagnosed malignancy among Indian women and a significant factor in cancer-related mortality. This study examines the reasons behind India's persistently elevated breast cancer mortality rates, despite increasing awareness and enhancements in healthcare infrastructure. Utilizing GLOBOCAN 2022 data, we examined age-stratified incidence and death trends and performed a Pareto analysis to determine the age groups that significantly impact the national illness burden. A comparative descriptive analysis of Mortality-to-Incidence Ratios (MIR) across India, North America, the United Kingdom, and South Korea was conducted to investigate global differences in cancer outcomes. The results show that women aged 35 to 79 make up the vast majority of breast cancer deaths in India. The MIR goes up continuously with age, which shows that there are long delays in finding the disease, unequal access to modern treatments, and ongoing problems with cancer registry reporting. The three high-income regions, on the other hand, had much lower MIR values. This shows how well systematic screening, early diagnosis, and integrated care pathways work, even though they are not yet fully in place in India. Pareto study showed that 85% of breast cancer diagnoses and deaths come from three main age categories: 35–49, 50–64, and 65–79. This shows which groups should be the focus of national screening and intervention programs. The paper also talks about the new possibilities of 3D bioprinting, which may make tumor models that are physiologically realistic, drug screening with high accuracy, and individualized solutions for reconstructive surgery after a mastectomy. Combining these biotechnological developments with public health policies could help India lower its breast cancer burden and make sure that everyone has better clinical results.

Keywords

Cancer, Breast Cancer, India, Mortality-to-Incidence Ratio (MIR), 3D Bioprinting

1. Introduction

Breast cancer is one of the most common types diagnosed in women globally and the leading cause of cancer-related fatalities in India. Urban areas have seen an annual growth rate of 5.2%, which may be linked to carcinogen exposure [1]. The incidence of breast cancer correlates strongly with age, showing a significant uptick during the menopausal and

post-menopausal years (ages 45-65), followed by a decline in later life. [1, 2]. Gaps in Indian cancer registries and limited access to advanced treatment often lead to late-stage detection, a primary driver of poor outcomes [3].

The increase in breast cancer incidence is multifactorial, resulting from the interaction of genetic, environmental, re-

*Corresponding author: bachanipooja@gmail.com (Pooja Bachani)

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productive, and behavioral risk factors. In India, this complex etiology is exacerbated by rising urbanization, increased life expectancies, postponed births, reduced breastfeeding rates, and the assimilation of Western lifestyles. [2] The demographic and lifestyle changes, commonly referred to as the epidemiological shift, have led to a significant increase in both the incidence and the percentage of cases diagnosed in postmenopausal women. However, what differentiates the Indian tale from that of high-resource nations like the United States, the United Kingdom, or South Korea is not merely the increase in cases but the consistently elevated mortality-to-incidence ratio (MIR). This singular statistic succinctly encapsulates the deficiencies in prompt detection, equitable access, and the continuity of quality care that afflict the Indian cancer landscape.

One promising development is 3D bioprinting—a revolutionary technology that uses bioinks and living cells to create three-dimensional tissues that mimic native human structures [4]. While still experimental, 3D bioprinting holds considerable potential for crafting precise cancer models, drug screening, and reconstructing tissues post-mastectomy. In the future, this technology could provide individualized ways to deal with and learn about the breast cancer burden.

2. Methodology

2.1. Data Source

Cancer incidence and mortality estimates were collected from the Global Cancer Observatory (GCO) “Cancer Today”

platform, which hosts the GLOBOCAN 2022 database (version 1.1, released on February 8, 2024). The incidence and mortality data were filtered and analyzed by age group (20-34, 35-49, 50-64, 65-79, and 80+).

2.2. Statistical Analysis

To find the age groups that were most responsible for breast cancer cases and deaths, we used descriptive statistics (mean and standard deviation) to conduct a comparative study of the MIR data. The investigation concentrated on delineating the central tendency and variability of MIR values throughout the four designated locations. Mortality-to-Incidence Ratio (MIR) between geographical regions (India, North America, the UK, and South Korea) was statistically significant.

3. Results and Discussion

3.1. Age-specific Burden in India

Indian epidemiological data reveal that the burden of breast cancer shows a positive correlation with increasing age (Table 1). The oldest age group (80+) bears the highest burden, with an Age-Standardized Rate (ASR) of 869.8 for incidence and 383.8 for mortality [5]. The increasing Mortality-to-Incidence Ratio (MIR) with age is a hallmark of a healthcare system that struggles with late-stage diagnosis and barriers to accessing effective treatment, especially for older women. [6, 7].

Table 1. Tabulated findings of incidence and mortality rate among Indian women.

Age Group	Incidence	Mortality	ASR (Incidence)	ASR (Mortality)	MIR
20-34	12087	3347	20.4	9.4	0.276
35-49	56219	20726	103.7	62.7	0.368
50-64	74752	38212	209.4	193.2	0.511
65-79	41102	28728	427.8	315.5	0.698
80+	16133	13944	869.8	383.8	0.864

ASR: Age-Standardized Rate; MIR: Mortality-to-Incidence Ratio

3.2. Pareto Analysis

In India, the age group of 50-64 years shows the highest uptick in both incidence (37.3%) and mortality (36.4%). The Pareto analysis identified that 85% of cases and deaths were concentrated in three age groups (35-49, 50-64, and 65-79),

highlighting these demographics as critical targets for public health intervention, as shown in Figure 1 and Figure 2 highlights women aged (50-64, 65-79 and 35-49) which accounts for 83.5% of total deaths in India. The younger and the oldest groups contribute minimally to the mortality burden of breast cancer in India.

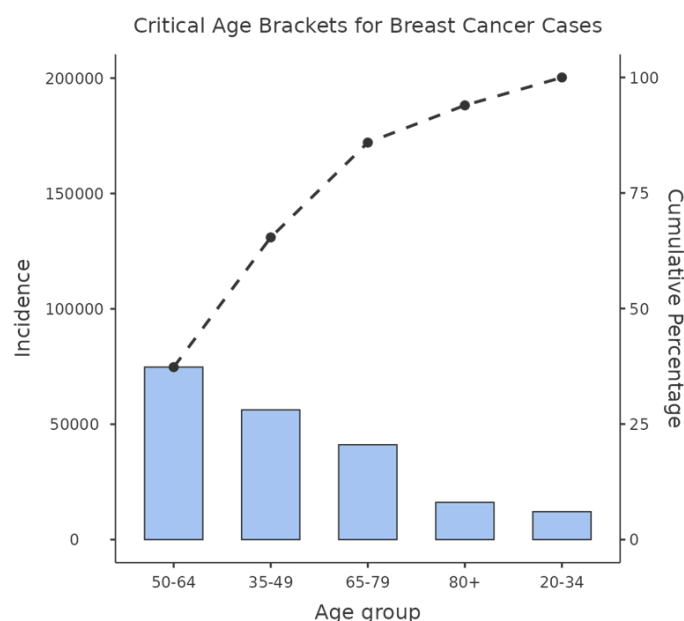


Figure 1. Pareto study of breast cancer rates in India by age group. The bar chart on the left displays the total number of new cases by age group, from highest to lowest. The line on the right shows the cumulative proportion, which reveals that three age groups (50-64, 35-49, and 65-79) make up 85.9% of all breast cancer cases.

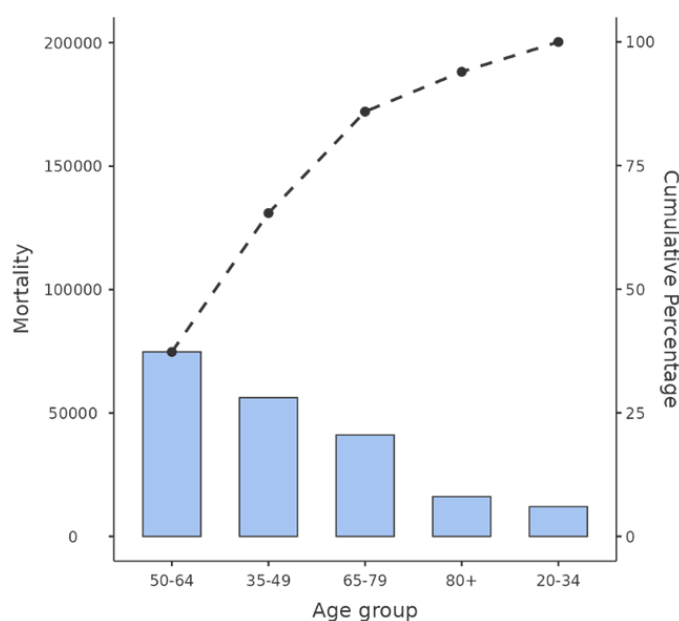


Figure 2. A Pareto study of breast cancer deaths in India by age group. The left y-axis shows the total number of deaths for each age group in order from highest to lowest. The right y-axis shows the cumulative percentage line, which shows that three age groups (50-64, 65-79, and 35-49) account for 83.5% of all breast cancer deaths. GLOBOCAN 2022 is the source of the data.

3.3. Descriptive Statistics

Descriptive results indicated that India has the highest mean MIR across the five age groups ($M = 0.544$, $SD = 0.239$),

in contrast to North America ($M = 0.152$, $SD = 0.103$), the UK ($M = 0.192$, $SD = 0.138$), and South Korea ($M = 0.168$, $SD = 0.166$) (Table 2). India's MIR was more than three times higher than that of high-income countries.

Table 2. Group Descriptives for MIR by Region.

Region	N	Mean (M)	SD	SE
India	5	0.544	0.239	0.107
North America	5	0.152	0.103	0.046
UK	5	0.192	0.138	0.062
South Korea	5	0.168	0.166	0.074

Table 2 shows that the mean MIR in India (0.544, SD = 0.239) was much greater than the averages in the USA (0.152, SD = 0.103), the UK (0.192, SD = 0.138), and South Korea (0.168, SD = 0.166). It is important to note that the three-fold difference in MIR between India and developed countries is not just due to more severe or more common cancers. It is also a reflection of problems at the system level. Higher death rates are caused by persistent problems with reaching people in rural areas, having diagnostic tools, having trained oncology workers, and having enough money to cover huge medical bills. These results show that India needs targeted interventions right away to fix its broken systems, fund population-based screening, make early treatment easier to get, and fill in the gaps in reporting and keeping an eye on cancer statistics.

The size of the gap reveals a clear difference, with India's average MIR being about three times higher than that of the other countries. This stark disparity underscores the profound impact of inadequate access to early detection, later-stage diagnosis, and unequal treatment infrastructure in India.³ In contrast, high-income countries benefit from robust screening and comprehensive care programs that minimize both MIR and age-based variability. Approximately 60–70% of breast cancer cases in India are identified at an advanced stage (stage III or higher), significantly diminishing the likelihood of successful treatment. The fundamental causes are: Insufficient Awareness: Numerous women, especially in rural and less-educated demographics, lack knowledge of early warning signals and the notion of breast cancer as a manageable condition. Stigmatization and Gender Barriers: Societal taboos inhibit candid discourse around breast health. Fear of social ostracism, perceived diminishment of femininity, or abandonment by partners are significant impediments to pursuing prompt care. Logistical obstacles, including travel durations to metropolitan areas, loss of daily earnings, and conflicting familial obligations, diminish the probability that women will finalize diagnostic evaluations or comply with treatment protocols.

The findings of this study underscore the need for policy interventions to improve access to affordable care. Initiatives like Ayushman Bharat are crucial steps. Concurrently, technological advancements like 3D bioprinting offer future potential. This technology provides powerful models for ana-

lyzing metastasis mechanisms and establishing superior platforms for drug screening compared to traditional 2D models [8-10]. Furthermore, it holds potential for creating customized tissue grafts for post-mastectomy reconstruction, thereby improving outcomes for survivors [11]. Broad surveys of 3D bioprinting in cancer research emphasize that such platforms can better recapitulate the tumor microenvironment, improve drug-response prediction, and reduce dependence on animal models. [12, 13]. By enabling construction of biomimetic breast tumour microenvironment models for drug testing and supporting patient-specific scaffolds for reconstruction, 3D bioprinting offers a practical pathway toward more precise and individualized breast cancer care [14, 15].

4. Conclusion

Based on the findings of this study, India must urgently expedite the implementation of organized breast cancer screening programs, particularly for women aged 35 to 79, when incidence and mortality rates are highest. A resilient healthcare infrastructure, decentralized diagnostic facilities, and a proficient medical workforce are essential for bridging early detection disparities and minimizing late-stage presentations. Integrating cancer registries with national health programs will facilitate thorough surveillance, enhance projection accuracy, and enable data-driven program assessment, thereby informing targeted policy actions and resource distribution.

In parallel, advancing oncological research and personalized care through emerging technologies like 3D bioprinting is essential. Bioprinting facilitates the creation of patient-specific tumor models, allowing for the investigation of metastasis, immune response, and treatment sensitivity. Clinically, it facilitates the development of personalized tissue grafts post-mastectomy, enhancing both functional and psychosocial results for survivors. By incorporating these technologies into standard cancer care and research, India can advance towards precision medicine and equitable results, providing optimism for significant advancements in the fight against breast cancer.

Abbreviations

MIR	Mortality Index Ratio
ASR	Age Standardized Rate

Author Contributions

Meghala Rajeev: Data Curation, Investigation, Visualization, Writing – original draft

Pooja Bachani: Conceptualization, Supervision, Project Administration, Writing – review & editing

Conflicts of Interest

Authors declare no conflict of interest.

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