Cureus
Part of SPRINGER NATURE

Open Access Original Article

Clinical Breast Examination Training With Virtual Reality: A Prospective Pilot Study of Knowledge, Practical Performance and Acceptability

Review began 09/18/2026
Review ended 10/05/2026
Published 10/28/2026

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DOI: 10.7759/cureus.118734

Diptendra K. Sarkar [1], Srija Basu [2], Rudradeep Banerjee [2], Amit K. Das [2], Sukanya Das [2]

1. Comprehensive Breast Services, Institute of Post Graduate Medical Education and Research, Kolkata, IND 2. General Surgery, Institute of Post Graduate Medical Education and Research, Kolkata, IND

Corresponding author: Srija Basu, srijabasu15@gmail.com

Abstract

Background

Clinical breast examination (CBE) is an important component of breast cancer screening in low- and middle-income countries, including India's National Programme for Prevention and Control of Non-Communicable Diseases. However, the accuracy of CBE is dependent on the examiner's technique, and opportunities for standardised, supervised and repeatable training remain limited. Virtual reality (VR) may provide an immersive and competency-based method of improving CBE training.

Methods

This prospective, single-centre, single-arm pre-test-post-test pilot study was conducted at the Institute of Post Graduate Medical Education and Research (IPGMER), Kolkata. Forty-three participants, comprising 22 doctors and medical students and 21 nurses, were enrolled. Baseline knowledge and practical CBE performance were assessed using a structured questionnaire and examination on a silicone breast model. Participants subsequently completed an interactive VR module in which each examination step had to be performed correctly before progression. Knowledge and practical skills were reassessed following training, and participants provided feedback regarding usability and acceptability.

Results

Knowledge and practical performance scores improved significantly following the VR intervention. Correct responses regarding breast palpation technique increased from 55.8% to 79.1%, assessment of the nipple and nipple discharge increased from 79.1% to 100%, use of the leaning-forward manoeuvre increased from 51.2% to 83.7%, and examination of all relevant lymph-node regions increased from 58.1% to 93.0%. The module demonstrated high acceptability: 97.7% of the participants considered VR more engaging and would recommend it, 95.3% reported that they perceived the VR format as helping them retain information, 90.7% found the module comprehensive, and 83.7% reported increased confidence in performing CBE.

Conclusion

Competency-gated VR training was feasible, well accepted and associated with immediate improvements in CBE knowledge and practical skills among healthcare professionals and medical students. VR may serve as a standardised and repeatable adjunct to conventional CBE training, particularly in resource-constrained screening programmes. Larger controlled studies should evaluate long-term skill retention, diagnostic accuracy, cost-effectiveness and real-world implementation.

Categories: General Surgery, Oncology, Healthcare Technology
Keywords: breast cancer screening, clinical breast examination, low- and middle-income countries, medical education, virtual reality

Introduction

Breast cancer is the most common malignancy among women in India. It is thus a major public-health challenge. GLOBOCAN 2024 estimated 237,231 new cases with 96,100 deaths in India, which amounts to 30.4% of all cancers diagnosed among women [1]. Identifying the need for a feasible population-level early-detection strategy, the Government of India, through the National Programme for Prevention and Control of Non-Communicable Diseases (NP-NCD), has adopted clinical breast examination (CBE) by trained healthcare providers as the screening tool for women aged 30 years and above, with referral of abnormal findings for further evaluation [2].

Indian community-based trials have provided evidence towards the use of CBE in resource-limited settings.

The 14-year follow-up data from the Trivandrum trial demonstrated improved survival and earlier stage detection among CBE-screened women, although there was no statistically significant long-term reduction in breast cancer-specific mortality [3]. The Mumbai trial found significant downstaging and a 30% reduction in breast cancer mortality in women aged above 50 years following biennial CBE by trained primary health workers [4].

However, CBE is operator-dependent. A major limitation in its large-scale implementation is the absence of standardised training. An examination performed incorrectly or incompletely may fail to cover the entire breast, use an inappropriate palpation technique, omit the nipple-areola complex or regional lymph nodes, and consequently miss small palpable lumps or produce inconsistent referral decisions [5,6]. Effective implementation of CBE under the national programme therefore requires structured and uniform training, objective assessment, immediate feedback and opportunities for repeated practice for all personnel involved in screening.

Conventional CBE teaching relies on lectures, demonstrations and supervised patient examination. Although these methods remain important, they may be limited by variation between trainers, restricted opportunities for repeated practice, patient availability, privacy concerns and shortages of expert faculty [5,6]. Virtual reality (VR) can provide an immersive, standardised and repeatable learning environment. Learners can perform the complete examination on a simulated patient, receive immediate reinforcement and progress only after correctly completing each step. The module can be repeated without patient discomfort or continuous expert supervision. VR-based healthcare education has shown improvements in knowledge, practical performance, confidence and learner engagement, and immersive systems have also been used to teach structured physical examination skills [7-9].

Despite the increasing use of VR in healthcare education, evidence regarding its application specifically to clinical breast examination training remains limited. Given the operator-dependent nature of CBE and the need for standardised, repeatable training that can be delivered consistently across learners, evaluation of a structured VR-based training approach is warranted. The objectives of this pilot study were to assess the immediate effect of a competency-gated VR training module on CBE knowledge, practical CBE performance on a silicone breast model, and participant-reported acceptability and usability of the training module among doctors, medical students, and nurses. This pilot study was undertaken to evaluate whether a standardised, competency-gated VR approach could improve immediate knowledge and practical performance while remaining acceptable and usable to learners.

Materials And Methods

Study design and participants

This prospective, single-centre, single-arm pre-test-post-test pilot study was conducted at the Institute of Post-Graduate Medical Education and Research and SSKM Hospital, Kolkata, India. The study included 43 healthcare participants: 22 doctors or medical students and 21 nurses. All had previously encountered the principles and steps of CBE through their undergraduate, postgraduate or professional curriculum; the intervention was therefore designed to reinforce and standardise existing knowledge rather than provide first exposure.

Participants from different professional backgrounds were included because the intervention was intended to evaluate a standardised CBE training approach across healthcare learners with previous curricular exposure to CBE. All participants received the same VR intervention and underwent identical pre- and post-training assessments. The primary analysis therefore evaluated the cohort as a whole, while comparisons between nurses and doctors/medical students were undertaken only as exploratory subgroup analyses.

As this was an exploratory pilot study intended to assess immediate changes in CBE knowledge and practical performance and to assess the acceptability and usability of the intervention, a formal hypothesis-driven sample-size calculation was not performed. The sample comprised participants with complete paired pre- and post-intervention assessments available during the study period. The findings were intended to provide preliminary estimates that could inform the design and sample-size calculation of a subsequent controlled study.

Ethics and consent

The study protocol was reviewed and approved by the Institutional Ethics Committee, IPGMER Research Oversight Committee, Institute of Post Graduate Medical Education and Research, Kolkata, at its meeting held on 22 August 2026 (memo no. IPGMER/IEC/2026/0385, dated 2 September 2026). Written informed consent was obtained from all participants before participation. All collected data were de-identified and analysed in aggregate.

Development and content of the VR model

The VR module simulated a complete clinical breast examination on a virtual female patient, beginning

with visual inspection in the recommended examination positions, followed by systematic palpation of the breast, examination of the nipple-areola complex, and assessment of the regional lymph-node basins, including the axilla.

The VR platform and technical module were developed by Roche India, while the clinical content relating to the sequence and components of CBE was developed/reviewed with input from the study investigators. Roche India provided technical training and implementation support for use of the VR system. Roche India had no role in participant recruitment, pre- or post-intervention assessment, collection of study outcome data, statistical analysis, interpretation of the results, or preparation of the manuscript, and did not have access to the de-identified analytical dataset. No monetary grant or research funding was received from Roche India for this study.

The educational intervention demonstrated the systematic sequence of CBE, including inspection in different positions, recognition of visible abnormalities, systematic palpation of the breast, examination of the nipple-areola complex, and assessment of regional lymph-node basins.

Assessment tools

Silicone breast models were used to assess practical skills before and after VR training. Theoretical knowledge was assessed using a structured 11-item questionnaire (Table *1*) covering the recommended age and frequency of CBE, purpose of examination, patient positioning, palpation technique, nipple and discharge assessment, the leaning-forward manoeuvre, lymph-node examination, follow-up after breast cancer, and recognition of suspicious findings. The questionnaire was developed by the study investigators to reflect the CBE domains covered in the training programme and was reviewed before use by faculty members experienced in breast surgery for relevance, clarity, and adequacy of content coverage. Each correct answer received one point, producing a total knowledge score ranging from 0 to 11.

Item	Question	Score
1	What is the recommended age for women to begin routine clinical breast exams (CBE) according to national guidelines?	Correct = 1, incorrect = 0
2	How often should women aged between 25-40 years with no special risk factors undergo a clinical breast exam?	Correct = 1, incorrect = 0
3	Which of the following is a primary purpose of performing a clinical breast exam?	Correct = 1, incorrect = 0
4	What is/are the positions to examine the breast?	Correct = 1, incorrect = 0
5	In the CBE, what technique is used to palpate the breast tissue?	Correct = 1, incorrect = 0
6	What should be checked during the CBE to assess possible discharge or abnormalities?	Correct = 1, incorrect = 0
7	What will “leaning forward” help us examine?	Correct = 1, incorrect = 0
8	Which area should be checked for lymph nodes during a CBE?	Correct = 1, incorrect = 0
9	If a patient reports a history of breast cancer, how often should they undergo a clinical breast exam?	Correct = 1, incorrect = 0
10	What sign during the CBE could indicate possible breast cancer?	Correct = 1, incorrect = 0
11	What are the areas to check for lymph nodes?	Correct = 1, incorrect = 0

TABLE 1: Pre- and post-training knowledge assessment of clinical breast examination knowledge

Scoring: The total knowledge score ranged from 0 to 11, with one point awarded for each correct response and zero points for an incorrect response.

Pre-training assessment

Before VR training, participants completed the questionnaire and then demonstrated CBE on a silicone breast model. A blinded independent assessor, who was not involved in the intervention, evaluated performance using a predefined 10-item checklist (Appendices). The assessment considered the sequence and completeness of inspection and palpation, coverage of breast tissue, examination of the nipple-areola complex and assessment of regional lymph nodes.

VR training intervention

Participants were then oriented to the headset and controllers and entered the immersive module. Within the virtual environment, each participant performed CBE on a simulated female patient. The programme guided the learner through patient positioning, inspection, palpation, nipple assessment and examination of regional lymph-node areas.

Progression was competency-gated, meaning that participants could proceed to the next stage only after correctly completing the preceding examination step. Incorrect or incomplete steps had to be repeated until the required step was completed correctly. There was no predetermined maximum number of attempts for an individual step; participants repeated the step until the module's completion criterion was met.

This design provided immediate reinforcement and required active performance rather than passive observation. The same virtual patient, examination sequence, instructional content, and progression criteria were used for all participants, thereby standardising delivery of the intervention.

Post-training assessment and participant feedback

Immediately after the intervention, participants completed a post-training questionnaire assessing the same domains and repeated the practical examination on the silicone model. The blinded independent assessor reassessed performance using the same scoring criteria.

Participants subsequently completed a structured feedback (Table *2*) form evaluating comprehensiveness, ease of understanding, independent navigation, perceived information retention, confidence, engagement, representation of the virtual patient and willingness to recommend the module. Additional questions asked whether all relevant examination positions and palpation sites were included, and free-text comments invited suggestions and reports of technical difficulties.

Item	Feedback question	Response format
1	At an overall level, did you find the video creating meaningful awareness?	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
2	At an overall level, did you find the video comprehensive?	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
3	At an overall level, did you find the video easy to comprehend?	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
4	Does the featured model represent the average Indian female body type?	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
5	Does the featured model represent the average age of an Indian woman undergoing breast cancer screening?	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
6	Do you feel all the positions for breast cancer screening were included?	Yes/No
7	If no, which positions for breast cancer screening need to be included?	Open-ended
8	How easy did you find it to navigate the virtual breast palpation on your own?	5-point scale: 1 = Very unsatisfied to 5 = Very satisfied
9	Do you feel all the sites for breast palpation were included?	Yes/No
10	If no, which sites for breast palpation need to be included?	Open-ended
11	The interactive nature of the VR helped me retain the information better.	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
12	I believe the VR training would enable me to detect early signs of breast cancer during screening.	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
13	I would recommend the VR training module to other healthcare professionals/fellow colleagues.	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
14	I found the VR module more engaging than traditional learning methods (textbooks, models and mannequins).	5-point Likert scale: 1 = Strongly disagree to 5 = Strongly agree
15	Please share your overall feedback regarding your experience of learning clinical breast examination through the VR module.	Open-ended

TABLE 2: Post-training VR module feedback questionnaire

VR: virtual reality

Study outcomes

The co-primary outcomes were the change in the total knowledge score and the change in practical CBE performance score from pre-training to immediately post-training assessment. Secondary outcomes included changes in item-level knowledge and participant-reported usability, engagement, confidence, perceived information retention, and acceptability. Pre- and post-training records were paired and de-identified before analysis.

Statistical analysis

Continuous variables are summarised as mean and standard deviation and, where relevant, median and interquartile range. Categorical variables are reported as frequencies and percentages. Paired-samples t-tests were used to compare pre- and post-training scores for the two co-primary outcomes, with mean differences, 95% confidence intervals and Cohen's dz reported.

Because improvement in both co-primary outcomes was required to demonstrate improvement across the two educational domains assessed, each co-primary outcome was evaluated using a two-sided significance level of 0.05. Wilcoxon signed-rank tests were used as non-parametric sensitivity analyses. Item-level changes in paired binary responses were assessed with exact McNemar tests, with Bonferroni adjustment for 11 comparisons. All tests were two-sided, and $p < 0.05$ was considered statistically significant. Statistical analyses were performed using Python version 3.13.5 (Python Software Foundation; Beaverton, Oregon, US) with SciPy version 1.17.0 (SciPy Developers; fiscally sponsored by NumFOCUS, Austin, Texas, USA).

Results

All 43 participants completed the pre-training and post-training knowledge assessments, silicone-model practical assessments and feedback questionnaire. Doctors and medical students comprised 51.2% of the cohort and nurses 48.8% (Table 3).

Characteristic	n	%
Total participants	43	100
Doctors and medical students	22	51.2
Nurses	21	48.8
Completed paired knowledge assessments	43	100
Completed paired practical assessments	43	100
Completed feedback questionnaire	43	100

TABLE 3: Participant profile and completion of study assessments

For overall knowledge scores (n=43), the median increased from 7 (IQR: 6-7) before training to 9 (IQR: 7.5-9) after training. The Wilcoxon signed-rank test confirmed a statistically significant improvement (p<0.001). The paired-samples t-statistics were t(42)=8.45 (p<0.001) for overall knowledge scores and t(42)=25.18 (p<0.001) for overall practical performance scores. The Wilcoxon signed-rank test was also significant for practical performance (p<0.001).

The mean knowledge score increased from 6.63±1.45 to 8.42±1.55 out of 11. The mean improvement was 1.79 points (95% CI: 1.36-2.22; t(42)=8.45; p<0.001), with a large effect size (Cohen's dz=1.29). The median score increased from 7 (interquartile range (IQR): 6-7) to 9 (IQR: 7.5-9), and the Wilcoxon analysis confirmed the result (p<0.001). Thirty-six participants (83.7%) improved, five (11.6%) were unchanged and two (4.7%) scored one point lower. Knowledge gains did not differ significantly between doctors/medical students and nurses (mean improvement 1.59 vs 2.00; p=0.337).

Practical performance improved from 6.40±0.69 to 9.70±0.46 out of 10. The mean increase was 3.30 points (95% CI 3.04-3.57; t(42)=25.18; p<0.001), with a very large effect size (Cohen's dz=3.84); the Wilcoxon test was also significant (p<0.001). Both co-primary outcomes demonstrated statistically significant improvement following the VR intervention (both p<0.001). All participants improved. Thirty scored 10/10 after training and 13 scored 9/10. In an exploratory subgroup analysis, nurses demonstrated a greater mean improvement in practical scores than doctors/medical students (3.62 vs. 3.00; p=0.016); this finding should be interpreted cautiously given the small sample and lack of adjustment for multiple subgroup comparisons (Table 4).

Outcome/group	n	Pre-training mean ± SD	Post-training mean ± SD	Mean change (95% CI)	Paired p-value	Cohen's dz
Knowledge: doctors/medical students	22	6.32±1.59	7.91±1.77	1.59 (0.88-2.30)	<0.001	1
Knowledge: nurses	21	6.95±1.24	8.95±1.07	2.00 (1.48-2.52)	<0.001	1.75
Knowledge: overall	43	6.63±1.45	8.42±1.55	1.79 (1.36-2.22)	<0.001	1.29
Practical: doctors/medical students	22	6.73±0.63	9.73±0.46	3.00 (2.64-3.36)	<0.001	3.67
Practical: nurses	21	6.05±0.59	9.67±0.48	3.62 (3.25-3.99)	<0.001	4.5
Practical: overall	43	6.40±0.69	9.70±0.46	3.30 (3.04-3.57)	<0.001	3.84

TABLE 4: Changes in knowledge and practical CBE scores following VR-based training

Paired-samples t-tests were used for the primary analysis; Wilcoxon signed-rank tests confirmed the overall findings.

Exploratory between-group comparison of mean change scores: practical CBE score, nurses versus doctors/medical students, p=0.016; knowledge score, nurses versus doctors/medical students, p=0.337. Between-group comparisons were performed using Welch's independent-samples t-test and were not adjusted for multiple subgroup comparisons.

CI: confidence interval; SD: standard deviation; VR: virtual reality; CBE: clinical breast examination

The largest item-level increase was in identification of all regional lymph-node areas, from 58.1% to 93.0%. Correct knowledge of the leaning-forward manoeuvre increased from 51.2% to 83.7%, breast-palpation technique from 55.8% to 79.1%, and nipple/discharge assessment from 79.1% to 100%. After Bonferroni correction, improvements remained significant for nipple/discharge assessment, the leaning-forward manoeuvre and identification of regional lymph-node areas (Table *5*).

Knowledge item	Pre-training correct n (%)	Post-training correct n (%)	Absolute change, percentage points	McNemar p-value	Bonferroni-adjusted p-value
Recommended starting age for CBE	21 (48.8)	29 (67.4)	18.6	0.039	0.424
Recommended CBE frequency among younger women	17 (39.5)	25 (58.1)	18.6	0.096	1
Primary purpose of CBE	38 (88.4)	41 (95.3)	7	0.25	1
Correct examination positions	39 (90.7)	42 (97.7)	7	0.25	1
Correct breast-palpation technique	24 (55.8)	34 (79.1)	23.3	0.021	0.234
Nipple and nipple-discharge assessment	34 (79.1)	43 (100.0)	20.9	0.004	0.043
Leaning-forward manoeuvre	22 (51.2)	36 (83.7)	32.6	0.003	0.028
Lymph node area to be examined	30 (69.8)	31 (72.1)	2.3	1	1
Recommended examination frequency after breast cancer	6 (14.0)	10 (23.3)	9.3	0.219	1
Recognition of a suspicious breast sign	29 (67.4)	31 (72.1)	4.7	0.727	1
Identification of all regional lymph-node areas	25 (58.1)	40 (93.0)	34.9	<0.001	0.003

TABLE 5: Item-level changes in knowledge following VR-based CBE training

Exact two-sided McNemar tests were used. Bonferroni correction was applied for 11 comparisons.

CBE: clinical breast examination

Acceptability was high. Forty-two participants (97.7%) would recommend the module and considered it more engaging than traditional teaching. Forty-one participants (95.3%) reported that they perceived the VR format would help them retain information; 39 (90.7%) considered the module comprehensive; 38 (88.4%) could navigate it independently and 36 (83.7%) reported increased confidence. All relevant examination positions were considered included by 93.0%, and 83.3% of respondents believed all palpation sites were covered. Ratings were lower for representation of the average Indian female body type (65.1%) and usual screening age (72.1%). Free-text comments described the module as interactive and memorable but requested clearer hand positioning, better coverage of the Tail of Spence and inframammary region, and correction of occasional blurring or disappearance of the avatar (Table *6*).

Evaluation domain	Valid n	Mean ± SD	Median (IQR)	Positive response n (%)
Created meaningful awareness	43	4.44 ± 0.77	5 (4-5)	41 (95.3)
Module was comprehensive	43	4.30 ± 0.64	4 (4-5)	39 (90.7)
Module was easy to understand	43	4.23 ± 0.81	4 (4-5)	35 (81.4)
Avatar represented average Indian female body type	43	3.91 ± 1.13	4 (3-5)	28 (65.1)
Avatar represented the usual breast-screening age	43	3.86 ± 0.99	4 (3-5)	31 (72.1)
Module was easy to navigate independently	43	4.09 ± 0.57	4 (4-4)	38 (88.4)
Perceived Improvement in information retention	43	4.40 ± 0.58	4 (4-5)	41 (95.3)
Increased confidence in detecting early signs	43	4.26 ± 0.93	4 (4-5)	36 (83.7)
Would recommend the module to colleagues	43	4.56 ± 0.55	5 (4-5)	42 (97.7)
More engaging than traditional learning	43	4.63 ± 0.62	5 (4-5)	42 (97.7)
All relevant examination positions were included	43	-	-	40 (93.0)
All relevant breast-palpation sites were included	42	-	-	35 (83.3)

TABLE 6: Participant evaluation and acceptability of the VR-based CBE module

Positive Likert responses were scores of 4 or 5. For the final two items, a positive response was 'Yes.'

IQR: interquartile range; SD: standard deviation; VR: virtual reality

Discussion

The principal finding of this pilot study was that immersive, competency-gated VR training produced significant immediate gains in both CBE knowledge and practical performance. The increase in knowledge was large, while the improvement in model-based practical scores was very large and occurred in every participant. The module therefore appeared particularly effective for reinforcing procedural sequence and completeness among learners who already had some curricular exposure to CBE. Unlike a lecture or demonstration video, the programme required participants to examine a virtual female patient and allowed progression only after successful completion of each step. This active, stepwise design may explain the pronounced practical improvement. Immediate correction, repetition and standardised sequencing reduce the possibility that a learner passively observes the procedure without mastering its individual components. Earlier studies have similarly shown that practice with feedback improves palpation technique and simulated lesion detection more effectively than lectures alone, while hybrid simulation can improve recognition of abnormalities, confidence and learner satisfaction [5,6]. Studies of VR-based neurological and general physical examination also support immersive technology as a useful method for teaching structured clinical tasks [8,9].

The largest knowledge gains involved regional lymph-node assessment, the leaning-forward manoeuvre, nipple/discharge assessment and palpation technique. These are procedural and spatial elements that may be difficult to communicate fully through text or conventional classroom teaching. A three-dimensional environment can demonstrate positioning, sequence and anatomical coverage consistently. Some items, however, showed limited change, including post-treatment examination frequency and recognition of a suspicious sign. These domains require clearer emphasis in future versions of the programme and review of questionnaire wording. Post-training practical scores clustered at 9-10, indicating excellent immediate performance but also a ceiling effect.

The module was highly acceptable. Almost all participants found it more engaging than traditional learning and would recommend it, while most reported improved confidence. These results support feasibility, but self-reported confidence should not be equated with competence. The perceived improvement in information retention was based on immediate post-intervention self-report and therefore should not be interpreted as evidence of objectively measured or sustained retention. Lower ratings for the avatar's body type and age highlight the importance of contextual design. Future modules should include virtual patients with varied ages, skin tones, body habitus and breast sizes. Participant suggestions regarding the Tail of Spence, inframammary fold, lower quadrants and nipple-areola complex should also be incorporated, together with clearer hand-position guidance and improved technical stability.

A major potential advantage of VR is standardisation. In India's population-based screening programme, CBE is undertaken at primary-care level by trained providers, including Community Health Officers, who identify abnormal findings and initiate referral [2]. Because CBE is operator-dependent, variation in training may produce missed steps, incomplete coverage and inconsistent referrals. A competency-gated module can provide the same instructions, sequence and minimum performance standard to learners across locations. It can also be repeated for refresher training without continuous access to an expert trainer or real patient. This may be valuable for geographically dispersed frontline workers and could reduce procedural errors, although programme-level benefit remains to be demonstrated. The study assessed both knowledge and objectively scored practical performance, included multiple healthcare groups and used an independent assessor. The intervention was interactive and uniform rather than a passive demonstration.

Future multicentre randomised studies should compare VR with conventional lectures, videos and instructor-led simulation. Assessments should include delayed testing, blinded checklist-based scoring, lesion-detection accuracy, communication, false-positive referrals and performance with standardised or real patients. Cost, equipment reliability, cybersickness, training time and feasibility within primary-care systems should also be evaluated. If these studies confirm sustained benefit, VR could provide a scalable adjunct for initial training and periodic retraining of Community Health Officers and other frontline providers.

Limitations

This study had a few limitations. First, it was a small, single-centre, single-arm pilot study without a control group, which limits causal inference and generalisability. Second, the same knowledge questionnaire and practical assessment process were used before and immediately after the intervention; therefore, repeated testing, familiarity with the assessment format and silicone breast model, and increased attention during the intervention may have contributed to the observed improvement. Third, outcomes were assessed only immediately after VR training, and the study therefore cannot determine whether improvements in knowledge and practical performance were sustained over time. Fourth, practical performance was assessed using a silicone breast model rather than real or standardised patients, and improvement in procedural scores may not necessarily translate into improved lesion-detection sensitivity, diagnostic accuracy, or referral decisions in clinical practice. The heterogeneous professional composition of the cohort may also limit interpretation of pooled results, and subgroup comparisons should therefore be considered exploratory. Detailed participant characteristics, including age, sex, years of clinical experience, previous formal CBE training, and previous VR exposure, were not systematically collected, limiting the assessment of whether these factors influenced the observed training effect. In addition, doctors and medical students were not separately coded in the source dataset, further limiting profession-specific comparisons. Finally, the VR system did not provide haptic feedback and therefore could not reproduce the tactile characteristics of breast tissue or palpable lesions. Altogether, larger controlled multicentre studies incorporating delayed assessment and real- or standardised-patient outcomes are required to determine the durability and clinical relevance of these findings.

Conclusions

Immersive, competency-gated VR training produced significant immediate improvements in CBE knowledge and practical performance and was highly acceptable to doctors, medical students and nurses. Its ability to deliver uniform instruction, immediate reinforcement and repeated practice supports its use as an adjunct for standardising CBE training, including refresher education for frontline healthcare workers in India. Larger controlled studies should assess long-term retention, diagnostic accuracy, referral quality, cost and real-world implementation.

Appendices

Item	Practical CBE assessment criterion	Score
1	Correct positioning and adequate exposure for breast inspection	0/1
2	Inspection with arms relaxed at the sides	0/1
3	Inspection with arms raised	0/1
4	Inspection of inframammary crease	0/1
5	Systematic palpation of the breast using an organised examination pattern	0/1
6	Correct palpation technique and pressure	0/1
7	Complete coverage of all breast tissue	0/1
8	Examination of the nipple–areola complex and assessment for discharge	0/1
9	Examination of the axillary lymph nodes	0/1
10	Examination of the remaining regional lymph-node basins	0/1
	Total	**0–10**

FIGURE 1: A predefined 10-item checklist used to evaluate the performance of participants in VR training.

VR: virtual reality

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Acquisition, analysis, or interpretation of data: Srija Basu, Diptendra K. Sarkar, Rudradeep Banerjee, Amit K. Das, Sukanya Das

Drafting of the manuscript: Srija Basu, Diptendra K. Sarkar, Amit K. Das, Sukanya Das

Concept and design: Diptendra K. Sarkar

Critical review of the manuscript for important intellectual content: Diptendra K. Sarkar, Rudradeep Banerjee

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. IPGME&R Research Oversight Committee issued approval IPGME&R/IEC/2026/0385. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

The authors sincerely acknowledge Roche India for designing and developing the virtual reality module used in this study and for providing technical training and support to the study team and participants. The authors also thank all the doctors, medical students and nursing personnel who voluntarily participated in the study.

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