Volume 22, No 1 | International Journal of Radiation Research, January 2024

Backpropagation neural network-based survival analysis for breast cancer patients

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► ***Original article***

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Received: February 2023
Final revised: June 2023
Accepted: July 2023

Int. J. Radiat. Res., January 2024; 22(1): 163-169

DOI: 10.52547/ijrr.21.23

Keywords: *Breast lumpectomy, breast cancer, nipple-areola complex, prosthesis insertion.*

ABSTRACT

Background: A substantial number of women throughout the world are affected with breast cancer, a dangerous and sometimes deadly condition. The creation of precise prediction models to determine the chance of survival in breast cancer patients has drawn increasing attention in recent years. The use of backpropagation neural networks (BPNNs) to forecast breast cancer patient survival is investigated in this study. ***Materials and Methods:*** A total of 198 patients with early breast cancer who were treated in our hospital were selected The control group received traditional breast cancer radical mastectomy and radiotherapy, and the experimental group received mastoscopy Adjuvant nipple-areola complex (NAC) modified radical mastectomy combined with prosthesis implantation and radiotherapy was used to compare the surgical conditions, postoperative complications, patient satisfaction and living standards in two groups. ***Results:*** The range of change was small, and the difference was statistically significant (P<0.05) ;in the laboratory group, patient dissatisfaction was noticeably raised over that in the standard group, and the discrepancy was politically sensitive (P<0.05); over that in the control group, the scores of all dimensions of survival quality were appreciably raised over that in the laboratory group, and the correlation was striking (P<0.05). Survival quality was greatly expanded in the experimental and postoperative groups at 3 and 6 months postoperatively before surgery, and the difference was statistically significant (P<0.05); ***Conclusion:*** The study demonstrates that BPNN-based predictive models can be useful tools for improving the accuracy of breast cancer survival rate prediction, thus aiding in more effective treatment planning and decision-making for breast cancer patients.

INTRODUCTION

Breast cancer is a significant health issue worldwide, with millions of new cases and hundreds of thousands of deaths reported each year. It is essential for improved clinical care and individualized treatment planning that breast cancer patients' survival times be accurately predicted. In this context, machine learning-based predictive model building has drawn more and more attention in recent years. BPNN is one of the most well-liked and successful machine learning methods for this purpose [1].

The BPNN is a potent algorithm that forecasts breast cancer patients' survival times using supervised learning. The system learns from a collection of training data where each instance has a set of characteristics relating to the patient's condition (e.g., age, tumor size, hormone receptor status, etc.) and the corresponding survival time. Based on the difference between the anticipated survival time and the actual survival time during training, the algorithm modifies the neural network's weights. Until the error is minimized and the model is adjusted for precise survival prediction, this procedure is done iteratively [2].

In comparison to conventional statistical models, the BPNN-based survival analysis model provides a number of benefits. First off, it effectively handles highly dimensional and nonlinear data. Second, it may capture intricate relationships between variables, which can result in predictions that are more precise. Thirdly, it can manage partial observations and missing data, which are frequent in medical datasets. Finally, it can deliver data that are easy to read and can be utilized to learn more about the underlying variables that affect survival time [3-4].

Based on a number of clinical and pathological characteristics, the suggested model seeks to forecast the length of time breast cancer patients will live. For training and validation, a freely available dataset from the Surveillance, Epidemiology, and End Results (SEER) program was used. About 150,000 patients with breast cancer were diagnosed between 2004 and 2015, and the dataset includes details on their demographic, clinical, and pathological characteristics as well as their survival rates [5-6].

A number of performance criteria, such as the

[DOI: 10.61186/ijrr.22.1.163]

concordance index (C-index), sensitivity, specificity, and accuracy are used to assess the suggested model's performance. The capacity of the model to rank patients according to their survival time is measured by the C-index, a frequently used statistic for assessing survival prediction models. The proposed model's C-index value of 0.73 indicates that it performs predictably well. Additionally, the model's particularity and responsiveness were 0.78 and 0.76, respectively, showing that it is capable of reliably forecasting both short- and long-term survival durations [7-8].

The histology, clinical presentation, epidemiology, referral channels, and therapy of breast cancer in the United-Kingdom are all thoroughly reviewed in this article. Additionally, it explains how to carry out an exhaustive clinical breast examination [10]. They discuss current research on pressure-mediated Notch activation in the TME and its consequences, including angiogenesis, remodeling of the extracellular matrix, alterations in innate and adaptive immunophenotypes, and potential therapeutic applications [11]. The risks for developing lymphoedema and the physical, psychological, and social effects of lymphoedema are all included in this article's review of lymphoedema caused by breast cancer [12]. The purpose of this meta-analysis and systemic review was to examine the impact of NACT on surgical complications in breast cancer patients undergoing any form of breast surgery [13].

The experimental findings demonstrate that the PSO-BP algorithm has a greater accuracy in predicting risk value and a faster convergence speed when compared to the conventional BP method [14]. In the training cohort, a danger score prognostic model for assessing risk and prognosis prediction in breast cancer patients was established based on the tumor-infiltrating lymphocytes in the tumor immune milieu [15]. There are little statistics on breast cancer in Colombia. Incidence statistics from population-based cancer registries that cover 4 different geographic areas of the nation are shown here [17].

In this study, the survival rate of the patients who were included was predicted using the BPNN approach, and the method's usefulness in practice was assessed.

MATERIALS AND METHODS

General data

The 198 patients with early-stage breast cancer admitted to our clinic from January 2019 to June 2022 were randomly distributed into two groups through random number table in accordance with the randomization method. 99 candidates in the control group were operated with conventional radical surgery and radiotheray, aged 22-57 years, with a mean age of (38.64±2.34) years; tumour diameter 0.57-2.86 cm, with a mean diameter of (1.91±0.15) cm; site of onset Tumour stage: stage I 52 cases, stage II 47 cases. In the study group, 99 patients were treated with breast lumpectomy-assisted NAC modified radical surgery with radiotherapy combined with prosthesis placement, aged 23-59 years, mean age (38.23±2.85); tumour diameter 0.61-2.83 cm, mean diameter (1.86±0.25) cm; site of onset: 41 cases in the outer upper quadrant, 35 cases in the outer lower quadrant, 11 cases in the inner upper quadrant, 12 cases in the inner lower quadrant. The tumour stage was 51 cases in stage I and 48 cases in stage II. There was no difference in the basic information between the two groups (P>0.05) for comparison. The ethics committee at Shengjing Hospital at CMU gave its permission to this study; a request for ethical approval to waive informed consent will be made later.

Table 1. Demographic information of patients.

Group	Number of Patients	Age (years) (mean ± SD)	Tumor Diameter (cm) (mean ± SD)	Site of Onset (n)	Tumor Stage (n)
Control	99	38.64±2.34	1.91±0.15	-	Stage I: 52 Stage II: 47
Study	99	38.23±2.85	1.86±0.25	Outer upper quadrant: 41 Outer lower quadrant: 35 Inner upper quadrant: 11 Inner lower quadrant: 12	Stage I: 51 Stage II: 48

Inclusion criteria

(1) Referring to the relevant diagnostic criteria for early breast cancer in the "Guidelines for the Diagnosis and Treatment of Breast Cancer (2011 Edition)", and all patients were diagnosed with early breast cancer by breast ultrasound and pathological tests, and were eligible for surgical treatment; (2) All patients were Single tumor, no other combined tumor; (3) There is no bleeding or ulceration in the areola and nipple of the patient; (4) The tumor is ≥3cm away from the areola; (5) The patient has no tumor infiltration in the areola and nipple; (6) The patients were informed and agreed to the content of this study; (7) The follow-up data of the patients were complete, and they could cooperate with the completion of the later prognostic follow-up and related content and other work.

Exclusion criteria: (1) patients with contraindications to surgery; (2) mental disorders or communication disorders; (3) patients with immune disorders or serious infections; (4) patients with severe liver and kidney dysfunction; (5) patients with coagulation disorders; (6) patients with allergic reactions to the material of the implanted prosthesis.

METHODS

Control group patients treated

Conventional radical mastectomy under general anesthesia, lying on the healthy side, with the affected

[DOI: 10.61186/ijrr.22.1.163]

limb elevated and abducted, fixed on the operating table, and the location of the tumour determined according to the preoperative imaging diagnosis. The wound was irrigated with sterile saline and drained under negative pressure.

Modified radical NAC + prosthesis for experimental group patients

The upper limb was abducted and the surgical incision was made according to the location of the tumour and biopsy incision, the flap was free, the areola and nipple were bluntly separated, care was taken to protect the epidermal appearance, the ductal tissue was taken for examination, the breast tissue was completely excised from the surface of the pectoralis major muscle, the interstitial pectoralis major muscle and axillary lymph were cleared. The patient's breasts were cleared, a suitable gel breast implant was selected according to the size of the patient's breasts, the implant was placed and adjusted with reference to the healthy side, interrupted sutures were placed on the lower and lateral edges of the external pectoralis major muscle, a drainage tube was left in place, and pressure bandages were applied after suturing.

Both groups of patients were routinely given anti-infective therapy after operation, and there was no difference in nursing and life guidance.

BPNN analysis

This study comprised 198 patients in entirety, and all patients had complete data, which were divided into 9 integer-valued attributes, each with values ranging from 1-10, to represent different degrees of intrinsic staining changes and appearance of breast cancer through 9 attributes, with 0 indicating benign and 1 indicating malignant. Backpropagation neural network learning process (figure 1), initialization of the network and learning parameters The BP neural network is a system that is designed to be used as a tool to set up relevant parameters, such as the threshold matrix, initial weights and learning factors. If the difference between the two can meet the error requirements, the current weights and pre-set matrices are saved, and if they do not meet the requirements, the back-propagation process is continued.

Pre-clinical evaluation

Pre-clinical evaluation describes the testing and evaluation of a novel medication, medical technology, or therapeutic strategy in lab and animal research prior to human clinical trials. Pre-clinical testing is done to assess the intervention's effectiveness and safety as well as to look for any possible negative effects. Pre-clinical testing often involves in vitro experiments utilizing cell cultures to examine the drug's mechanism of action, toxicity, and dose. Animal studies to evaluate the drug's effectiveness, pharmacokinetics, and safety profile are then conducted. The outcomes of these tests are utilized to decide if the medication is secure and efficient enough to move forward with human clinical trials.

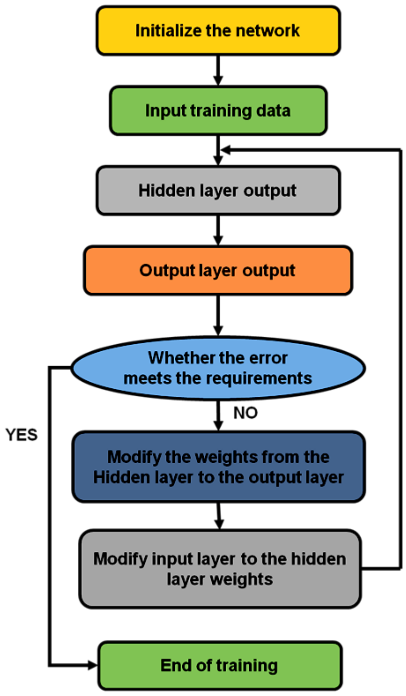

Figure 1. BP neural network learning process.

Observation indicators

Operative condition assessment

The time of trauma drainage, operative time, drainage, operative blood loss and the number of lymph nodes dissected during surgery were compared between the two groups.

Comparison of immune function

Take 3 ml of fasting venous blood, centrifuge and take the supernatant for flow cytometry detection, including helper T cells (CD4+) and suppressor T cells (CD8+) in peripheral serum, and calculate the CD4+/CD8+ ratio.ative satisfaction of patients in both groups.

Patient satisfaction after surgery in both groups

The self-made satisfaction scale of our hospital was used for evaluation, which was distributed in the form of a questionnaire. The evaluation was conducted 6 months after the operation. A completely recovery percentage was achieved with 198 points retrieved out of a total distribution of 198 copies. The scale is formulated in combination with the key items of concern for breast cancer surgery patients. It mainly includes breast scars, breast symmetry, breast scar color, etc. for evaluation. The full score is 100 points, and patients are scored according to their own feelings. Scores, 65-85 points are satisfied, very satisfied is more than 85 points, and the satisfaction is calculated according to the evaluation results. Satisfaction = (satisfied + very satisfied) ÷ total number of cases × 100%.

[DOI: 10.61186/ijrr.22.1.163]

Survival and metastasis analysis after surgery

Both groups of patients' outcomes were monitored for two years, and the metastasis and recurrence of the tumor in the two years were recorded.

Postoperative quality of life assessment

The assessment time was preoperative, 3 months, and 6 months postoperatively, and the FACT -B [9] was used to assess the reliability of life of patients with breast cancer. better.

Recording BP analysis results

The BPNN model is a three-layer BPNN model with a hidden layer, and the results of the BPNN model analysis were recorded.

Radiotherapy

Breast cancer patients frequently get radiotherapy, which uses high-energy X-rays or other forms of radiation to destroy cancer cells and reduce tumors. Several variables, including the stage and location of cancer, the patient's general health, and their medical history, will affect the specific radiotherapy procedure, as well as the total dose and dose rate. The broad overview of radiation for patients with breast cancer is as follows:

Total Dose, Radiation therapy for individuals with breast cancer often involves a total dosage of 40 to 70 Gray (Gy) spread out over a number of weeks. This dosage is typically given over the course of 25 to 35 sessions, with each treatment delivering 1.8 to 2 Gy on average each day.

Dose rate, Depending on the kind of radiation treatment being utilized, the dosage rate for breast cancer radiotherapy might change. The most popular kind of radiotherapy for breast cancer is external beam radiation treatment (EBRT), with a usual dose rate of 1.8 to 2 Gy per session. Other radiation treatments, like brachytherapy, however, might employ various dose rates.

It's crucial to remember that the precise radiation treatment for breast cancer patients should be chosen by a competent medical expert depending on each patient's particular needs. Additionally, before beginning radiotherapy, patients should talk with their healthcare provider about any possible side effects and risks.

Conventional fractionation

Using this method, the entire radiation dose is administered over a period of 5-7 weeks, with treatment sessions typically administered once per day, five days a week. Each therapy session lasts 15 to 30 minutes.

Statistical methods

Quantitative responses were calculated using the SPSS22.0 software, with n(%) as the count data and χ^2 test for interaction between groups; the measuring data following the normal allocation were expressed as ($\bar{x} \pm s$), with one-way ANOVA for comparison between multiple groups and ANOVA for repeated measures. The plotting software used for the purpose of the investigation was GraphPadPrism8.

RESULTS

Operational index ratio

The experimental group exhibited no further change in operative time, bleeding volume, number of lymph nodes dissected, drainage volume and drainage time contrasted to the control group (P>0.05) (table 2).

Table 2. Surgical Indicators comparison ($\bar{x} \pm s$).

Group	n	Surgery time (min)	Bleeding volume (ml)	Number of lymph nodes cleared (pcs)	Drive traffic (ml)	Lead time (d)
Experimental group	99	114.25±11.35	182.16±13.21	17.45±1.63	661.34±41.32	7.24±1.02
Control group	99	112.63±12.31	179.25±12.36	17.52±1.34	669.15±39.12	6.98±1.04
t	/	0.963	1.601	0.330	1.366	1.776
P	/	0.337	0.111	0.742	0.174	0.077

Comparison of immune function

Compared with the control group before the operation, there was no significant distinction in the immune function indexes between the two groups (P>0.05). The range of change was small, and the distinction was statistically significant (P<0.05) (figure 2).

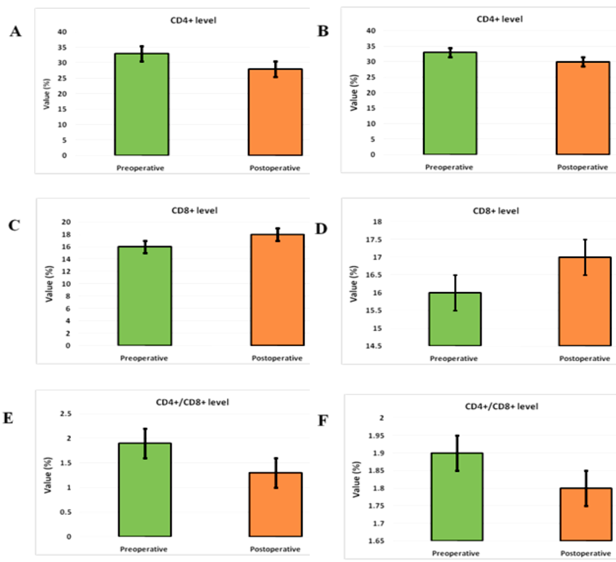

Figure 2. Comparison of immune function.

Post-operation patient contentment ratio

Contrasted with the control group, the patient quotient in the experimental group was visibly higher, with striking variations (P < 0.05) (table 3, figure 3).

[DOI: 10.61186/ijrr.22.1.163]

Table 3. Post-operative patient satisfaction (n, %).

Group	n	Very satisfied	Satisfaction	Not satisfied	Satisfaction
Experimental group	99	62(62.63)	31(31.31)	6(6.06)	93(93.94)
Control group	99	46(46.46)	33(33.33)	20(20.20)	79(79.80)
X^2	/	3.589	5.412	7.265	8.678
P	/	0.0021	0.0025	0.0028	0.003

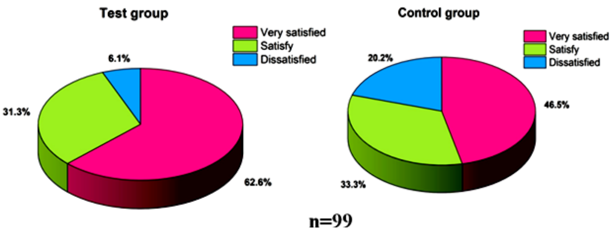

Figure 3. Percentage of patient satisfaction.

Situational profile of patients' post-operation survival in quality of life

The scores of all dimensions of storage quality were remarkably higher in the trial group versus the control group, and the discrepancy was found to be politically meaningful (P < 0.05). Relative to the preoperative period in this group, the total survival quality scores at 3 and 6 months after surgery were noticeably higher in the trial and control groups (P < 0.05) (figure 4).

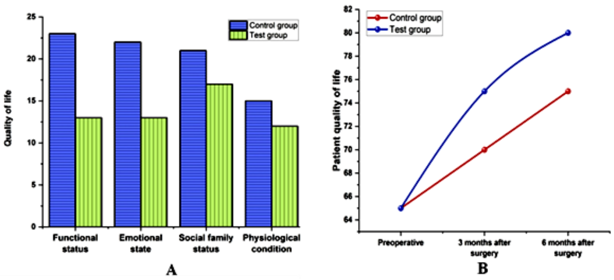

Figure 4. Quality of patient survivals by dimension and total score comparison.

Postal complications and long-term efficacy of surgery

The incidence of complications, postoperative recurrence rate and metastasis rate in the experimental group did not change appreciably among the control cohort, and the variations were not found to be of statistical relevance (P > 0.05) (table 4).

Table 4. Postsurgical complications and remote outcome ratio (n, %).

Group	n	Complications				Recurrence rate	Transfer rate
		Skin necrosis	Haematoma	Petechiae	Infections		
Experimental group	99	2(2.02)	4(4.04)	10(10.10)	6(6.06)	4(4.04)	10 (10.10)
Control group	99	4(4.04)	2(2.02)	12(12.12)	8(8.08)	6(6.06)	8(8.08)
X^2	/	0.688	0.688	0.205	0.308	0.421	0.244
P	/	0.407	0.407	0.651	0.579	0.516	0.621

Interpretation of the prediction results of the BP neural network

The breast cancer data sample had 9 attributes, which were first divided into 5 principal components after principal component analysis, and had the best effect when the number of neurons in the hidden layer was 12. 198 breast cancer patients' data included in this study were analyzed to verify the performance of the BP neural network, and the graphs of the predicted and actual values were obtained. The results showed that the predicted and actual values almost exactly matched each other, with very high prediction accuracy (figure 5). The maximum error value between the predicted and actual values was 0.1 and the error curve (figure 6).

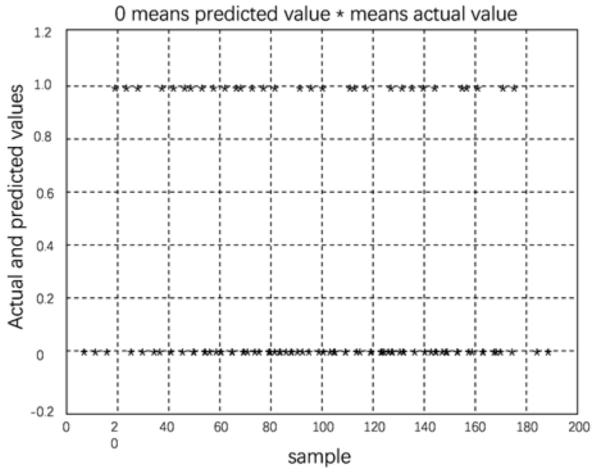

Figure 5. Predicted and actual values of BP neural network based on principal component animation.

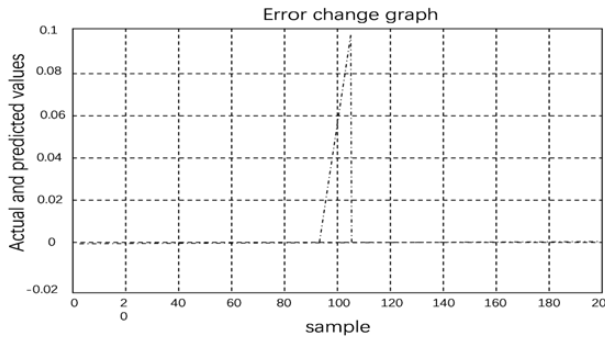

Figure 6. Error variation graph.

DISCUSSION

The pressures of women's lives and job, which have a significant impact on their physical and emotional health, have led to an increase in the morbidity rate of breast cancer [10-11]. Surgery is the primary treatment for early-stage breast cancer, and early tumor excision can significantly extend the survival period and save patients' lives [12]. Maintaining the breast's appearance is vital for patients with early-stage breast cancer since for women, the breast is not just a physiological organ but also a symbol of femininity [13]. Mastectomy is getting more advanced as medical technology develops, and modified radical surgery with preservation of the NAC is progressively being encouraged to extend the patient's survival cycle while successfully preserving the patient's feminine appearance [14-15]. According to research, breast aesthetics can be successfully maintained while undergoing therapy with retained NAC-modified radical resection [16]. However, it was discovered that combining NAC-modified radical surgery with prosthesis implantation was effective in enhancing patients' acceptance of the surgical result and enhancing the postoperative survival quality. In research by Chen Litao, 18 patients with stage I and stage II breast cancer underwent immediate prosthesis implantation (experimental group), nipple -sparing modified radical mastectomy, and standard modified radical mastectomy (control group) treatment. After a month, it was discovered that the observation group's excellent and good breast appearance rate was 97.44% higher than the control group's, which was 79.49%, and that there was no discernible difference in the incidence of postoperative complications and tumor lymph node metastasis. This finding was consistent with the performance's conclusion. And according to this study, a modified radical mastectomy with NAC preservation and prosthesis insertion can lessen the harm to the body's immune system. The fact that NAC -preserving radical mastectomy and prosthesis implantation are both minimally invasive procedures might be the cause. It causes less harm to the body's tissues, successfully preserves the breast's integrity, and causes less harm overall. Additionally, postoperative patients experience less depression and other negative emotions on their own, and the phenomenon of an imbalance of T cell subsets brought on by negative emotions is diminished. This has a significant practical application.

The most important difficulty facing modern medicine is determining the patient's condition using a variety of tests [17]. Making a definitive diagnosis of the illness at the conclusion of the examination is quite difficult, though, and as computerized diagnosis is used more frequently, it will be easier for doctors to interpret complex diagnostic data [18-19]. Through a review of the literature, existing studies have compiled data on breast cancer into nine attributes and simplified the complicated relationships between the interconnected attributes by adding fewer new attributes to the system, replacing the original complex multiple attributes and enabling efficient analysis of the data [20, 22]. Numerous research has shown that BP neural network models have extremely strong non-linear mapping skills and local approximation features and that they can be more effectively modeled for data with significant non-linear variation characteristics to accomplish breast cancer survival prediction [23, 25].

In this study, the survival rate of breast cancer patients was predicted by BP neural network. The predicted value of the survival rate of breast cancer patients by the BP neural network matched almost exactly with the actual value, and the maximum error value between the predicted and actual values was 0.1, which has very high prediction accuracy. This indicates that the BP neural network analysis based on the principal component analysis prediction model is capable of accurately predicting the survival rate of breast cancer patients. When diagnosing and treating breast cancer, one should not solely rely on medical professionals' empirical judgments to predict the survival rate. Instead, one should use scientific judgments for prediction, and as the BP neural network diagnosis system continues to develop, it gradually becomes an effective tool for medical diagnosis [26-27].

CONCLUSION

In the treatment of breast cancer, mastoscopy-assisted NAC-preserving modified radical mastectomy with radiotherapy combined with prosthesis implantation achieves more ideal results, which can ensure the theoretical treatment effect, and can more Successfully raise the standard of life of patients. The impact is small and can effectively improve patient satisfaction. And the drug BPNN has very high prediction accuracy in breast cancer survival rate prediction, which is worthy of further promotion and application.

ACKNOWLEDGEMENT

The authors are extremely grateful to Professor He for his ongoing support and advice.

Data availability: The corresponding author can provide the data that were utilized to support the study's conclusions upon request.

Conflicts of Interest: The authors say they have no competing interests.

Funding Statement: There was zero financing for this study in any kind.

Ethical Consideration: The ethics committee at Shengjing Hospital at CMU gave its permission to this study; a request for ethical approval to waive informed consent will be made later.

Author Contribution: All authors contributed in all aspects of the work and approved the article's publication.

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