Mathematical modelling for analysis and interpretation of the adverse effect in breast cancer patient during their therapy and improvement in recovery

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Abstract

Develop and use Mathematical modelling has emerged Fuzzy Cognitive Maps (FCM) as important tool for improvement of recovery in breast cancer patients during their therapy. There are number of adverse effects observed in cancer patients during their treatment. Some common adverse effects like physical, psychological, social, spiritual, visible and medical disorders are observed during breast cancer therapy. Extra proliferations of breast cell in the form of tumor are breast cancer. The better understanding of the adverse effects of breast cancer therapy might be helpful for effective treatment and faster recovery of patients. By lowering the adverse effects the chances of increase in patient recovery and cure become better. In current work use mathematical modelling through concept of Fuzzy Cognitive Mapping (FCM) is applied to interpret the relationship between different adverse effects that out break during breast cancer therapy .Identification and understanding of the adverse effects of breast cancer therapy and their interpretation through mathematical modelling may be useful tool for better treatment with faster recovery.

Keywords: Mathematical Modelling, Breast cancer, Fuzzy Cognitive Maps (FCM), adverse effect, Breast cancer therapy

INTRODUCTION

Mathematics is primarily the foundation of all objects. Every complication of any subjects can be solved by mathematics. Subjects like social science, life science, economics, nature and human life behavior can be dwelt with it. It can be asserted that every deal or task has straightly or incidentally is related or confide on mathematics.

Mathematical modelling is helpful in serving corrective guidance for complications of medical science i.e. Heart ailments, Diabetes, cancer, other vital organs of human body with blood disorders. Mathematics is important tool providing latest approach to check the different

disease and aliments of human being. Mathematics solves the problems. The world is facing the cancer spread it become essential to discover the common causes an prevention for cancer. Mathematical modelling can assist in breaking the challenging cancer complications. Applied mathematics can interpretate by practical experimental work the basic and rational links of the cancer complications. Mathematical modelling abstracted on the fundamental issues can elucidate the medical problems. As per WHO appraisal 6 million people die every year. During normal physical process the old or damaged cells get replaced by new cells formation but in case the formation of new cells is in excess than the growth, extra cells form tissue mass formed tumor or cancer. Cancer may grow in any part of the body. As per the requirement of human body new cells form and divide in natural process but when cell division continues with no end, the abnormal growth of unrequired new cells result in tumor or cancer. The abnormal growths of cells do not form healthy tissues and tumor is formed. The cancer gene or oncogene is the outcome of mutation resulting in tumor or cancer. As the cancer develops by unrestricted cell growth gradually spreading in others parts or organ know as metastasis. Programmed death is called apoptosis. When apoptosis process is stopped down cancer begins to form. The abnormal cells causing cancer are developed multiple division of cells.

Basically mathematic prevention for is the backbone of everything. It has solution of every complication related with all aspects of life. It deals with nature, life sciences and social and economic as well as behavior of life. So we can assert everything directly or indirectly is connected or depend upon mathematics. mathematical modelling help in solving problems related with medical field like blood flow, diabetes, cancer and heart diseases. It gives the right and proper solution for prevention or cure from diseases and gives the new ideas or strategies to control these diseases. Actually cancer is commonly spread disease in the whole world nowadays. It is very necessary to find out the causes as well as preventions of cancer. Cancer modeling is one of the challenging tasks, which sort out the problems with the help of mathematical modeling. Applied mathematics provides the base or framework of logical links for the problems which can be interpreted by experimental work. Mathematical modeling focused on basic issues can interpretate medical problems. First of all we discuss some terms related with human body and cancer. WHO estimated that, 6 million people die by cancer annually.

Sometimes new cells form when the body doesn't need them and old or damaged cells don't die then buildup of extra cells often forms a mass of tissues called a growth of cancer or tumor.

Cancer may develop in any part of the body. Normally our body cells grow and divide to

form new cells according to the need of human body but if cells divide without end or cells grow abnormally new cells grow without any need this kind of growth is termed tumor or cancer. Tumor is basically masses of tissues. In this process abnormal cells do not develop in healthy tissues they divide rapidly and form tumor , according to "Math digest", a cancer gene or "oncogene" is gene, by outcome of resulting in mutation cancer is responsible for cancer, As cancer is generated by uncontrolled cell growth, gradually spreading in other parts or organs called "metastasis". Programmed cell death is called "Apoptosis", when this process is break down cancer began to form. After this cells divided into abnormal cells and cause cancer.

Breast cancer

Breast cancer is the most common disease diagnosed among the women with over 1.3 million per year. Recently the researchers found that breast cancer is increasing in low income countries. In India breast cancer is now the second leading cause of death after cardio vascular disease and the reason is observed change in life style daily routine or westernization or change in reproductive behavior. Breast cancer is the malignant tumor which starts in the cells of the breast. Malignant cancer is infected and spread in organs and other parts of human body.

A female breast is made up of lobules (milk producing glands), ducts (tiny tubes that carry the milk) and stoma (fatty tissues and connective tissues surrounding the ducts and lobules, blood vessels and lymphatic vessels). Most breast cancer begins in the cells that line the ducts (ductual cancer), some lobules (lobular cancers) and some in other tissues. The breast cancer is uncontrolled with higher death rate disease worldwide. Mostly identified in last stage and there are less options for its treatment. In this paper we worked on effect of harmful chemical substances which are vigorously responsible for breast cancer. After all prevention is better than cure so avoid the use, contact of contaminated articles by these carcinogenic compounds shall decrease the rate of breast cancer.

WORLD CANCER PREVALENCE

Table-1

Type of cancer	Breast cancer	Prostate	Colorectal cancer	Gynecologic	Other Genitourinary cancer	Hematologic	Melanoma	Lung cancer	Other Cancer
Percentage	22%	6%	19%	9%	10%	8%	6%	3%	17%
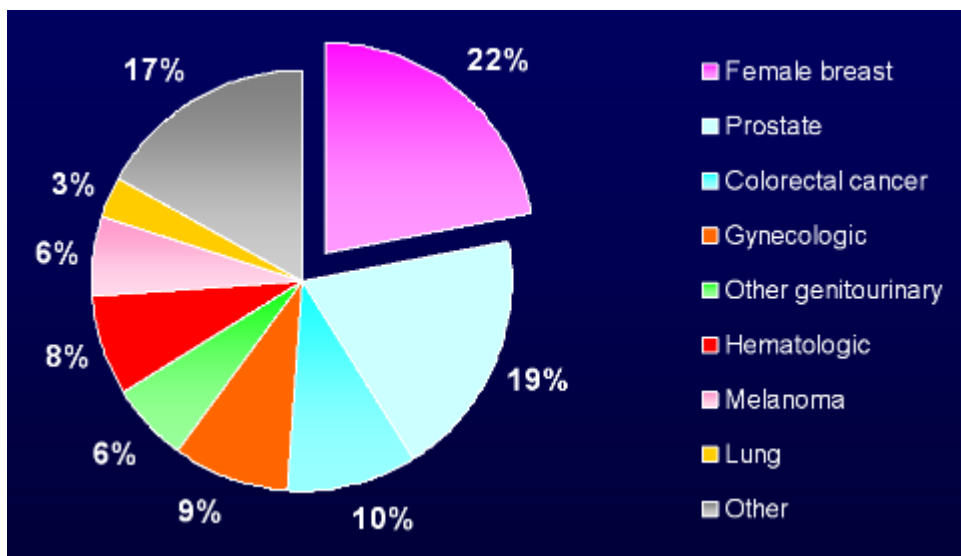
Prevalence database. US estimated complete prevalence counts released by NCI, DCCPS based on the SEER data submission.

Table - 2

Age Range	10 – 19	20 – 29	30 – 39	40 – 49	50 – 59	60 – 69	70 – 79	80 +
JNCH	10	58	64	71	47	61	20	6
CMCRC	6	26	22	38	19	28	18	4
Total	16	84	86	109	66	89	38	10
Percent	3.21%	16.87%	17.27%	21.89%	13.25%	17.87%	7.63%	2.01%
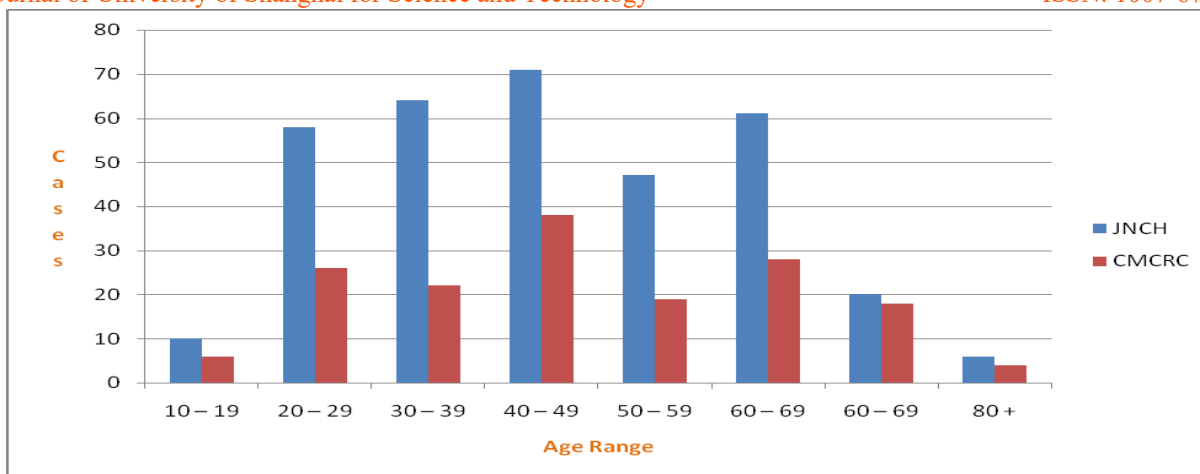
The graphical presentation of table 2 showing the total distribution of patients based on age ranges in both hospitals (JNCH : Jawaharlal Nehru Cancer Hospital   CMCRC: Chirayu Medical College and Research Center)

Table - 3

Line of cancer treatment and cure	Adverse effect
Surgery	Bleeding, blood clots, damage to nearby tissues, pain and infection
Radiation therapy	Fatigue, skin irritation, fever and mild-faint
Chemotherapy	Damage in many organ cells like the bladder, heart, kidneys, lungs and nervous system as well as hair follicles
Targeted Cancer therapy	Skin problem, intense itching, allergies in skin, difficulty in breathing and dizziness

These long-term and late side effects may include:

- Fatigue

- Headache

- Pain and numbness (peripheral neuropathy)

- Dental issues

- Lymph edema

- Musculoskeletal symptoms

- Bone loss and osteoporosis

- Heart problems

- New cancers

- Cataracts

- Blood clots

- Absence of menstrual periods

- Menopausal symptoms

- Sexual difficulties

- Infertility

- Concerns about memory loss and cognitive function

Mathematical model helps to observe and reduce the adverse effect in cancer patient during the time of their treatment. In this paper we discuss about different adverse effect in cancer patient during treatment. Mathematical modelling is method by which we design mathematical model that can increase patients medical counseling system, patients care system and reduce adverse effect that appear during breast cancer therapy

Adverse effect of breast cancer therapy:

Following adverse effect has been observed in breast cancer patient on the time of treatment therapy.

1. Physical effect
2. Psychological effect
3. Social effect
4. Spiritual effect
5. Visibility effect
6. Medical disorder

1. **Physical effect :** Decreased functional capability, Diminished strength, Weakness endurance, Nausea, loss of appetite, Poor or interrupted sleep, lack of energy. Fatigue

2. **Psychological effect :** Increase anxiety, fear, depression, personal distress, difficulty in concentration, loss of emotional control, anorexia, insomnia, mental stress, Feel guilty, Loss of confidence,

3. **Social effect :** Society withdrawal symptoms, Diminished social relationships, affection, altered appearance, difficulty in following social role.

4. **Spiritual effect :** Increased suffering, altered meaning, reevaluation of religious belief, insecurity of life

5. **Visibility effect :** Hair fall, weight loss or weight gain, skin problems, mouth sores,

6. **Medical disorder :** GIT disorder (imbalanced metabolic process), Nervous system impairment, bleeding or bruising, Anemia, infection, Ulcer, chemo induced peripheral neuropathy(CIPN), skin hyper pigmentation, Lymphedema, Multiple organ dysfunction syndrome (MODS)

Fuzzy Cognitive Maps

In the field of mathematical modelling, Fuzzy cognitive maps always attract the researchers for better solution of real world problems. Draw graph and analyzing complex real biomedical problems by knowledge of Fuzzy cognitive maps. In Fuzzy cognitive maps tables are used for mapping and converting into matrices system for further calculation. FCM is used to solve decision making problems, modelling, biological and biomedical, complex systems. Fuzzy cognitive maps is well developed system implemented for social scientific knowledge and modeling decision making in social and biomedical systems. Fuzzy cognitive maps have obtained sufficient research interest because of their efficiency in developing structured information and modeling systems in various fields. This growing interest led to the required for increase and making result promising models that can better represent real world problem and help to find out the appropriate solution..

The application and implementation of Fuzzy cognitive maps system is used in broad area of research and development like:

Fuzzy cognitive maps -based methodology is useful for

- In business for product planning and decision making.
- In economics for decision policy and economical balance system.
- In education for learning management systems.
- In medical for diagnosis, treatment and medical assessment.
- In engineering for complex systems and reliability engineering
- In project planning and analyzing the mutual dependencies between project resources.

- In computer to check whether students understand their lessons.

- In IT sector for risk analysis, assessment and IT scenarios

The common terminology and concepts used in Fuzzy cognitive maps (FCM) are:

1. Fuzzy cognitive maps are graphs with belief like decision, planning, management, diagnosis etc. as nodes and causality as edges. It applies to develop causal relationship between concepts.

    - If there are increment or decrement of one concept, the other one also show same increment or decrement automatically and finally we find value 1

    - If there are no correlations between two concepts, finally we get the value 0.

    - If there are increment of one causalities and other one decrease, finally we get the value –1

2. The edge weights from the set $\{-1, 0, 1\}$ in Fuzzy cognitive maps then its called simple FCMs.

3. In Fuzzy cognitive maps the C_1, C_2, C_3,…………………,C_n are taken as node or concepts Drawn the directed graph by using edge weight $e_{ij} \in \{0, 1, -1\}$. In Fuzzy cognitive maps always adjuvant with square matrices and diagonal entries as zero. The matrix E specified by E= e_{ij}, where e_{ij} is the weight of the directed edge C_iC_j, here E is known as the adjacency matrix of the Fuzzy cognitive maps, it is also known as connection matrix.

4. Let C_1, C_2, C_3,…………………………..,C_n be the nodes of an Fuzzy cognitive maps, E =(E_1, E_2, E_3,………, E_n), where $E_i \in \{0, 1\}$. E is said to be the instantaneous state vector and it designate the on-off position of the node at an instant.

    $E_i = 0$ if E_i is off and

    $E_i = 1$ if E_i is on

    for i = 1,2,3,……….., n

5. Let C_1, C_2, C_3,…………………………..,C_n be the nodes of an Fuzzy cognitive maps. Let

$$\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \overrightarrow{C_3C_4} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots, \overrightarrow{C_iC_j}$$

be the edges of the Fuzzy cognitive maps.

This may be cyclic if it possesses a directed cycle and connected in a closed chain or acyclic possesses if it does not possess any directed cycle that never come back to the same node by rotating the edges.

6. $\overrightarrow{C_1 C_2},\ \overrightarrow{C_2 C_3},\ \overrightarrow{C_3 C_4}$ ...., $\overrightarrow{C_{n-1} C_n}$

Fuzzy cognitive maps follow the cyclic dynamical system run round and round like C_i is in switched ON position and if the causality flows through the edges of a cycle and if it again causes C_i considering counting. This is exact for any node C_i for i=1, 2, 3,..........................,n . The equilibrium state for this dynamical system is called the hidden pattern.

Develop Mathematical Model by Fuzzy Cognitive Maps

Induced fuzzy cognitive maps are advance evaluation approach of Fuzzy cognitive maps. In induced fuzzy cognitive maps as per need of the model there is some revisal in algorithms. To find out the appropriate solution of current problem apply the following steps

1. For the study of model, collect the appropriate data that is in determined factors called nodes. In this model symptom of breast cancer is taken as arbitrary attribute.
2. As per the opinion of subject expert and oncologist, draw the directed graph.
3. Draw the directed graph (FCMs) to obtain the connection matrix, 'B'. In connection matrix, 'B' the number of rows in matrix are equal to number of arbitrary attribute.
4. Taken the state vector E_1 which is in ON position. Find C_1 X B. The state vector is modernized and threshold at each stage is noted.
5. Take the first component of this vector E_1 in ON position which is represented by 1 and the rest of the components as 0 which are in OFF position.
6. At each stage the state vector is modernized and threshold. The symbol ' ' describe the threshold value for the product of the result. The threshold value is calculated from C_1 X B by assigning 1 for the values $x_1 > 0$ and assigning 0 when $x_1 < 0$.
7. The value is calculated by assigning 1 for the relation between any two symptoms (arbitrary attributes) otherwise assigning 0. The product of the result is denoted by $\rightarrow$ sign.
8. The product of the given matrix is calculated taken separately each component of C_1. In above calculation which vector has maximum number of one`s now it is considered as C_2.
9. Taken as fixed point when the same threshold value become twice and the iteration gets finished. If threshold is not the same value then again the matrix is multiplied by C_2 vector and follow the calculations discussed in steps 4 to 7.
10. Sustained the above process for all the rest state vectors and then find out the appropriate solution.

Adverse effect has observed in cancer patient on the time of their treatment.

ANALYSIS OF THE MATHEMATICAL MODEL,

A Mathematical model for most probable adverse effect has observed in breast cancer patient during their therapy. For the present study we take following six arbitrary attributes (E_1, E_2, E_3, E_4, E_5, E_6).

E_1 = Physical effect

E_2 = Psychological effect

E_3 = Social effect

E_4 = Spiritual effect

E_5 = Visible effect

E_6 = Medical disorder

The directed Graph is describe by using adverse effect (arbitrary attributes) of breast cancer therapy.
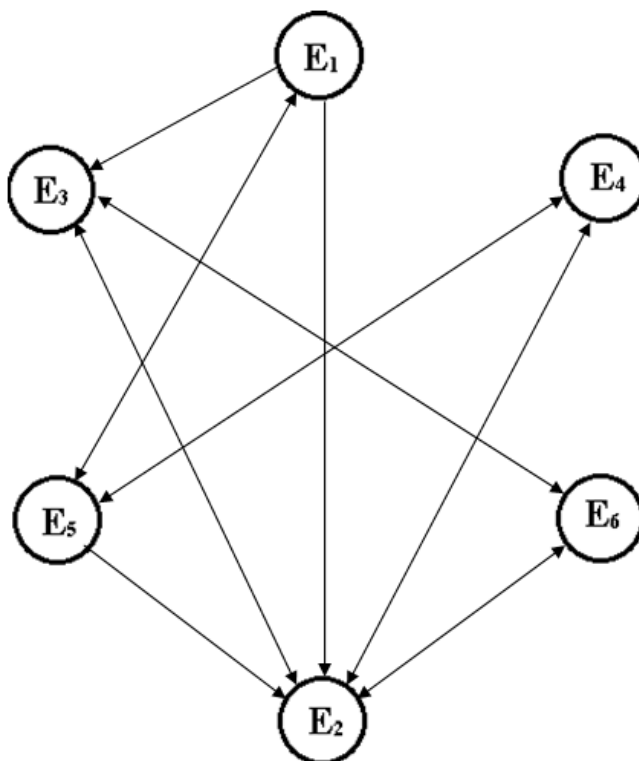

Fig (1) : Directed graph by using adverse effect of breast cancer therapy.

IMPLEMENTATION OF MATHEMATICAL MODEL

On the basis of the study we identifiy and understand the adverse effect of breast cancer therapy.

Here the step-in-aid of the execution of the model. We created a matrix 'B' by using fig (1)

$$B = [b_{ij}] = \begin{array}{c} \\ E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \end{array} \begin{array}{c} E_1\ E_2\ E_3\ E_4\ E_5\ E_6 \\ \begin{bmatrix} 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 \end{bmatrix} \end{array}$$

.......................(1)

To interpret the adverse effect of breast cancer therapy here Induced Fuzzy Cognitive Maps method has been used. Initially E_2 (Psychological effect) are taken to interpret the problem. Here we supposed that only E_2 (Psychological effect) states are ON and others effect are OFF. Then,

$C_1 = (0\ 1\ 0\ 0\ 0\ 0)$ .... (2)

Multiply C_1 with matrix 'B'

$C_1B = (0\ 0\ 1\ 1\ 0\ 1)$

i.e.,

$C_1^1B = (0\ 0\ 1\ 1\ 0\ 1)$ ... ...(3)

It is known that the threshold value is calculated by assuming one (1) for individual relation between adverse effect of breast cancer therapy and zero (0) if there is no relation.

Now, calculation for threshold values by iteration method, in this process we suppose in ON position one by one

all E_i's as we supposed for E_1, So,

$$(1\,0\,0\,0\,0\,0)B \to C_1^1 B \sim (0\,1\,1\,0\,1\,0) \qquad \ldots\ldots\ldots\ldots\ldots (4)$$

$$(0\,1\,0\,0\,0\,0)B \to C_1^1 B \sim (0\,0\,1\,1\,0\,1) \qquad \ldots\ldots\ldots\ldots\ldots (5)$$

$$(0\,0\,1\,0\,0\,0)B \to C_1^1 B \sim (0\,1\,0\,0\,0\,1) \qquad \ldots\ldots\ldots\ldots\ldots (6)$$

$$(0\,0\,0\,1\,0\,0)B \to C_1^1 B \sim (0\,1\,0\,0\,1\,0) \qquad \ldots\ldots\ldots\ldots\ldots (7)$$

$$(0\,0\,0\,0\,1\,0)B \to C_1^1 B \sim (1\,1\,1\,1\,0\,0) \qquad \ldots\ldots\ldots\ldots\ldots (8)$$

$$(0\,0\,0\,0\,0\,1)B \to C_1^1 B \sim (0\,1\,1\,0\,0\,0) \qquad \ldots\ldots\ldots\ldots\ldots (9)$$

Let

$$C_2 = (1\,1\,1\,1\,0\,0) \qquad \ldots\ldots\ldots\ldots (10)$$

Because the threshold having maximum 1`s will be assumed as C_2, then repeat the above process again, So,

$$C_2 B = (0\,3\,2\,1\,2\,2) \qquad \ldots\ldots\ldots\ldots\ldots (11)$$

Here equation (11) will be considered as the result of the mathematical model to interpret adverse effect of breast cancer therapy by using Fuzzy Cognitive Maps.

$$= (0\,3\,2\,1\,2\,2)$$

CONCLUSION

On completion of process following major outcomes of the interpretations are obtained:

- ❖ When we put E_2 (Psychological effect) in ON position, we found that the result is (0 3 2 1 2 2) which is shown in equation (11).

- ❖ Here second adverse effect has maximum value 3. It means that peoples who are suffering from cancer, the adverse effect i.e. psychological effect (E_2) is observed mostly. By the reduce level of Psychological effect in cancer patens increase the effect of treatment therapy with better patients' recovery.

- ❖ In this result the adverse effect E_3 (Social effect), E_5 (Visible effect) and E_6 (Medical effect) have also higher value 2. Appearance of these three adverse effects in breast cancer patients during their therapy but if it has been over looked or previously mentioned adverse effect are also present then it need to be patient, family members and physicians make attention and take appropriate action for reducing the adverse effect. To conducted patients' health counseling by medical specialist and increase will power of patients by their family member and motivational well fare society.

  By organized social awareness and motivational program by cancer hospitals and conduct seminars by other governing body for betterment of cancer patients. The family

members of cancer patient provide moral and emotional support for faster recovery and cure.

❖ In this model the value of E_1 (Physical effect) and E_4 (Spiritual effect) are found to be 0 & 1 respectively that means both are minor adverse effects of breast cancer therapy. The reason behind these are minor adverse effect which will appear in less, even not appear in most patients. The probability of these adverse effects will be rare. If major adverse effect E_2 will be reduced then the effect of E_1 and E_4 will also be reduced automatically. The meditation and social interaction is also helpful in reducing both E_1 and E_4.

FUTURE SCOPE OF THE RESEARCH

Here we design mathematical model work as an intelligent system that can be enhance patients medical counseling system, patients care system, awareness in the society and definitely it reduces adverse effects that appear during breast cancer therapy and enhance patients faster recovery process. Decreased the adverse effect in breast cancer patients definitely increase the rate of recovery, cure and save many lives.

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