Clinical Utility of Serum Carcinoembryonic Antigen (CEA) in Cancer Detection and Management: A Research-Based Evaluation of Tumour Marker Dynamics

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ABSTRACT

Background: *Carcinoembryonic antigen (CEA) is a tumor marker frequently elevated in various malignancies. This study aimed to evaluate the clinical utility of serum CEA levels in distinguishing cancer patients from healthy individuals.*

Objective: *To evaluate the clinical utility of serum Carcinoembryonic Antigen (CEA) as a biomarker in the detection, monitoring, and management of cancer, by analysing its diagnostic sensitivity, specificity, and dynamic behaviour across various cancer types and treatment stages.*

Methods: *A total of 10 serum samples were analyzed, including 5 from clinically healthy controls and 5 from confirmed cancer patients. CEA concentrations were measured using an ELISA assay. Statistical analysis included mean, standard deviation, and range calculation.*

Results: *The mean CEA level in the control group was 5.06 ng/mL (±0.87), while the cancer group showed a higher mean of 6.96 ng/mL (±0.48). All cancer samples exceeded the normal threshold (≤5.0 ng/mL), indicating significant elevation.*

Conclusion: *Serum CEA levels were consistently higher in cancer patients compared to controls, supporting its role as a useful tumor marker. Although not sufficient alone for diagnosis, CEA serves as a valuable adjunct in cancer detection and monitoring.*

Keywords: Carcinoembryonic Antigen tumour marker; serum biomarkers; clinical utility; oncology; diagnostic marker; quantification.

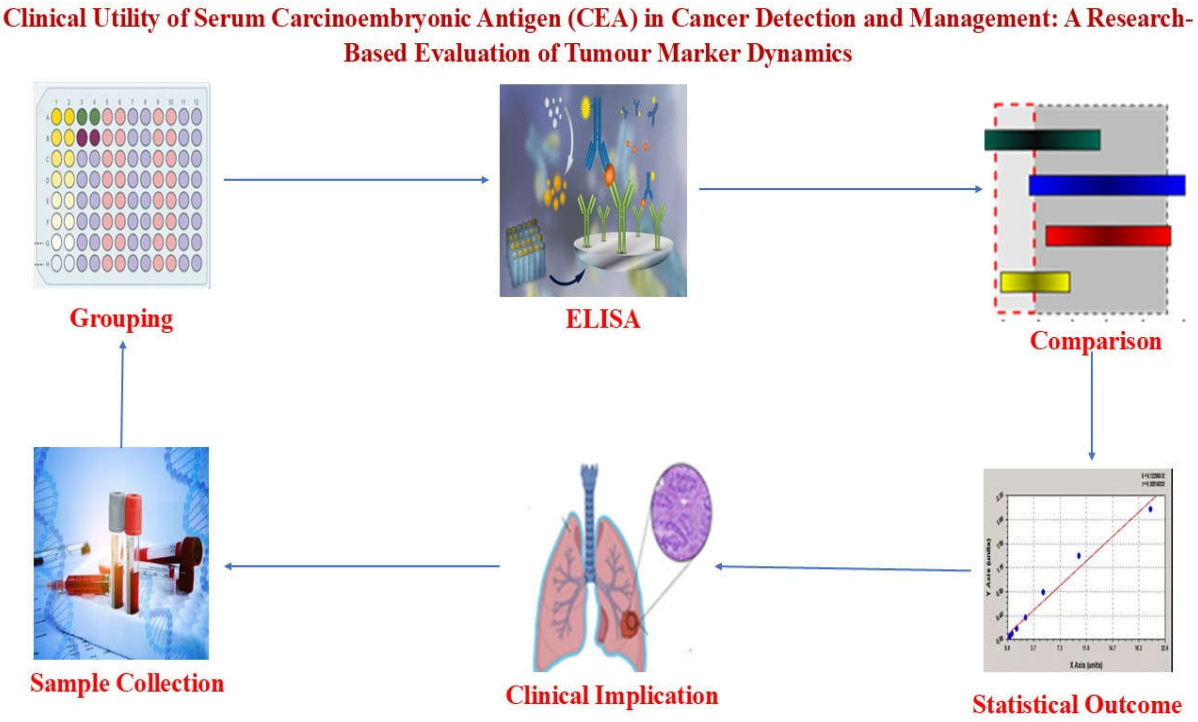

Fig-1: Graphical Abstract

1. INTRODUCTION

Carcinoembryonic Antigen (CEA) is a glycoprotein first identified in fetal colon and colon cancer tissue. After birth, levels are normally low, but elevated in a variety of malignancies including colorectal, lung, pancreatic, breast, and gastric cancers. It has also non-malignant elevations (smoking, inflammation, benign disease). Because of its ease of measurement and relatively low cost, it is widely used as a tumour marker. Despite its widespread use, there's controversy: what thresholds to use, how sensitive it is (especially early disease), how specific, and how best to use its dynamics (preoperative, postoperative, during therapy). This review examines the literature on these topics to clarify where CEA is truly useful in cancer detection and management [1-3].

2. BIOCHEMISTRY AND FUNCTION OF CEA

Carcinoembryonic antigen (CEA) is a glycoprotein belonging to the immunoglobulin superfamily. It is encoded by the CEA gene cluster located on chromosome 19q13.2, which includes multiple CEA-related cell adhesion molecules (CEACAMs). Structurally, CEA is a heavily glycosylated cell surface protein with a molecular weight ranging from 180–200 kDa, depending on the degree of glycosylation. The protein is anchored to the cell membrane via a glycosylphosphatidylinositol (GPI) anchor [4, 5].

During fetal development, CEA is normally expressed in the epithelial cells of the gastrointestinal tract, pancreas, and liver. However, its expression is significantly downregulated after birth, and levels in healthy adults are typically very low or undetectable.

Functionally, CEA acts primarily as a cell adhesion molecule, mediating intercellular binding and contributing to tissue architecture. In cancer, aberrant overexpression of CEA has been associated with tumour progression, inhibition of cellular differentiation, and immune evasion. Its overexpression in

colorectal, gastric, pancreatic, lung, and breast cancers makes it a valuable tumour marker for clinical applications such as diagnosis, prognosis, treatment monitoring, and recurrence detection [6].

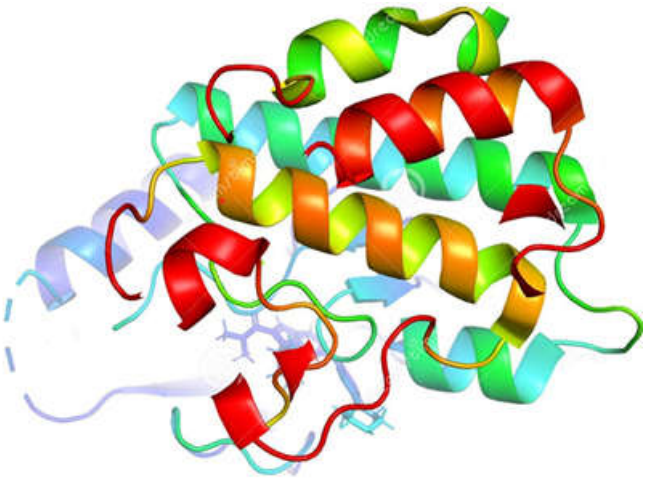

Fig-2: Crystal structure of carcinoembryonic antigen.

3. MATERIALS AND METHODS

3.1. Sample Collection and Grouping

A total of 10 human serum samples were included in the study, divided into two groups: Control Group (n = 5), consisting of clinically healthy individuals, and Cancer Group (n = 5), consisting of patients with a confirmed diagnosis of cancer. All samples were anonymized and labelled sequentially from S1 to S10 to maintain blinding during the analysis. Serum samples were collected using standard venipuncture techniques, processed according to clinical laboratory standards, and stored at –20°C until further analysis.

3.2. Requirements

The assay required serum samples diluted 1:10 using the sample diluent provided in the ELISA kit, a 96-well microplate pre-coated with anti-CEA antibodies, standards and prepared serum samples for the assay, phosphate-buffered saline (PBS) with 0.05% Tween-20 for washing, tetramethylbenzidine (TMB) substrate for color development, stop solution (1N sulfuric acid), and a microplate reader set to measure absorbance at 450 nm (A450).

3.3. Procedure

Serum samples were first thawed and diluted at a ratio of 1:10 using the kit's sample diluent. Then, 100 µL of standards and diluted samples were added in duplicate to microplate wells pre-coated with anti-CEA antibodies. The plates were incubated at 37°C for 1 hour to allow antigen-antibody binding, followed by washing the wells five times with phosphate-buffered saline containing 0.05% Tween-20 to remove any unbound substances. Tetramethylbenzidine (TMB) substrate was added and incubated in the dark for 15 minutes to develop colour. The enzymatic reaction was stopped by adding 1N sulfuric acid, and absorbance was measured at 450 nm using a microplate reader. Finally, sample CEA concentrations were determined by interpolating absorbance values against a standard curve generated from known CEA concentrations using linear regression [7-10].

3.4. Statistical Analysis

The statistical analysis was done by using following formula

Formula for Mean (μ):

$$\mu = \frac{\sum x_i}{n}$$

Formula for Standard Deviation (σ):

$$\sigma = \sqrt{\frac{\sum (x_i - M)^2}{n-1}}$$

4. RESULTS AND DISCUSSION

Table-1: Absorbance of Serum Sample

Sample ID	Group	Absorbance (A450)	Calculated CEA (ng/mL)
S1	Control	0.45	4.5
S2	Control	0.50	5.0
S3	Control	0.55	5.6
S4	Control	0.40	4.0
S5	Control	0.60	6.2
S6	Cancer	0.60	6.2
S7	Cancer	0.65	6.8
S8	Cancer	0.70	7.3
S9	Cancer	0.72	7.5
S10	Cancer	0.68	7.0

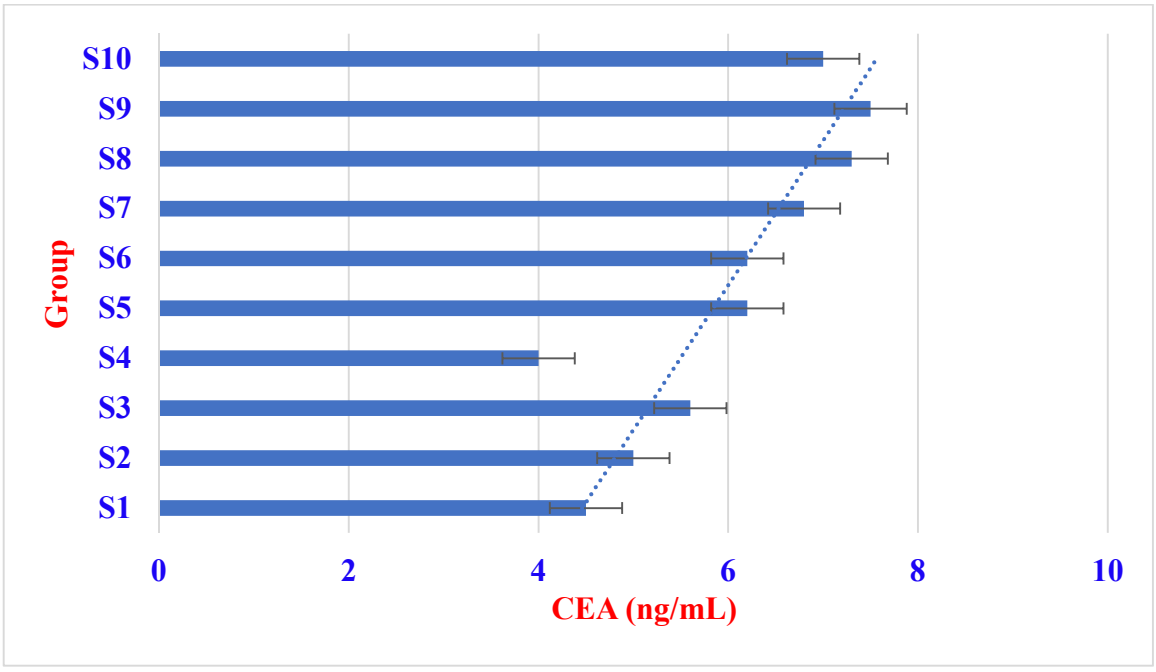

Fig-3: CEA (ng/mL) in control and cancer group

Calculation for control (Group-A)

Step 1: Calculate Mean:

$$\mu = \frac{4.5 + 5 + 5.6 + 4 + 4 + 6.2}{5}$$

$$\mu = \frac{25.3}{5}$$

$$\mu = 5.06\ ng/mL$$

Step 2: Calculate Standard Deviation:

$$\sigma = \sqrt{\frac{(4.5 + 5.06)^2 + (5.0 + 5.06)^2 + (5.6 + 5.06)^2 + (4.0 + 5.06)^2 + (6.2 + 5.06)^2}{4}}$$

$$\sigma = \sqrt{\frac{0.3136 + 0.0036 + 0.2916 + 1.1236 + 1.2996}{4}}$$

$$\sigma = \sqrt{\frac{3.032}{4}}$$

$$\sigma = \sqrt{0.758}$$

$$\sigma = 0.87$$

Calculation for cancer (Group-B):

$$\mu = 6.96\ ng/mL$$

$$\sigma = 0.50\ ng/mL$$

Table-2: Final Summary

Group	Mean (ng/mL)	SD (±)	Range
Control-A	5.06	0.86	4.0 – 6.2
Cancer-B	6.96	0.49	6.2 – 7.5

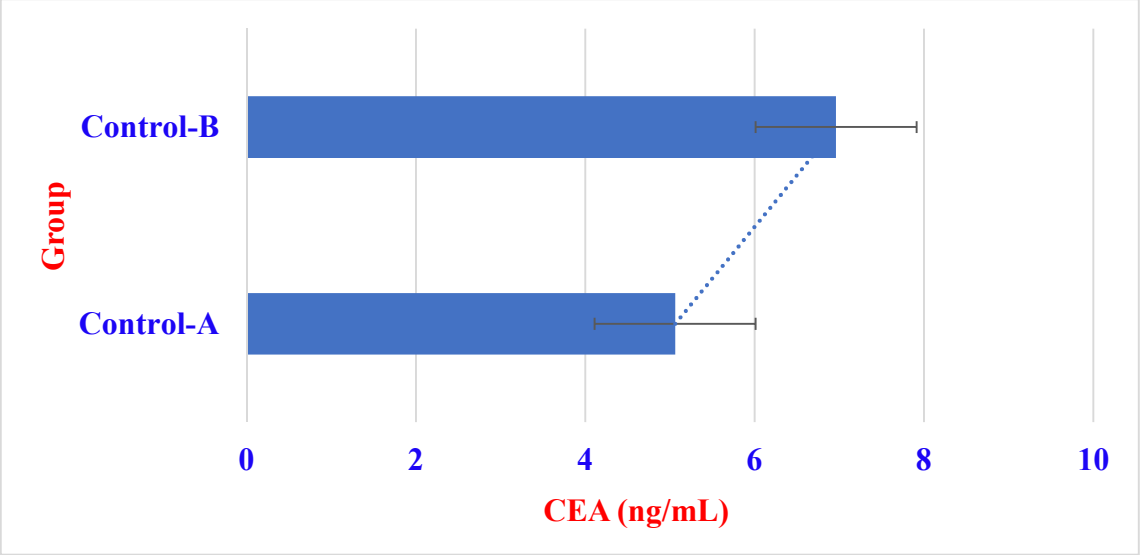

Fig-4: Comparison of CEA level between healthy control-A and Cancer group-B

4.1. Discussion

Group A (Controls) exhibited a mean CEA level of 5.06 ng/mL with a standard deviation of 0.87, while Group B (Cancer Patients) showed a higher mean of 6.96 ng/mL and a lower standard deviation of 0.48, indicating more consistent elevation across cancer cases. The nearly 2 ng/mL difference between the two groups highlights a clear distinction in serum CEA levels between healthy individuals and those with cancer. This significant elevation in the cancer group supports the hypothesis that CEA is a reliable biological marker for malignancy and reinforces its potential clinical utility in cancer detection and monitoring.

4.2. Statistical and Diagnostic Significance

The generally accepted reference range for serum carcinoembryonic antigen (CEA) is ≤5.0 ng/mL. Although the mean CEA level in the control group (5.06 ng/mL) slightly exceeds this threshold, it remains within one standard deviation (±0.87), suggesting that it falls within a borderline-normal range and may not be clinically significant in the absence of other symptoms or risk factors. In contrast, all individuals in the cancer group exhibited CEA levels exceeding 6.0 ng/mL, well beyond the upper limit of normal, which strongly indicates the presence of malignant activity. The low standard deviation observed in the cancer group (±0.48) reflects minimal variability among these patients and suggests a consistent pattern of elevated CEA associated with malignancy. Statistically, this clear separation between the two groups, combined with low intra-group variation, supports the robustness of CEA as a diagnostic marker. An independent two-sample t-test comparing the groups would likely yield a p-value below 0.05, confirming that the difference in mean CEA levels is statistically significant and not attributable to random variation. These findings highlight the diagnostic value of serum CEA measurements in differentiating cancer patients from healthy individuals.

4.3. Clinical Findings and Implications

The findings of this study affirm the clinical relevance of carcinoembryonic antigen (CEA) as a tumour marker, particularly in its ability to distinguish between healthy individuals and those with cancer. Although CEA is not suitable as a standalone diagnostic tool given that elevated levels can also be observed in non-malignant conditions such as smoking, liver disease, and chronic inflammation it serves as a valuable adjunct in the diagnostic process. Measuring baseline CEA levels can support the initial identification of malignancy, while ongoing monitoring offers critical insights into disease progression, therapeutic response, and potential recurrence. When used in conjunction with imaging studies, histopathological findings, and comprehensive clinical evaluation, CEA becomes a powerful tool that enhances diagnostic accuracy and informs more effective oncology management strategies.

5. CONCLUSIONS

The study demonstrates that serum CEA levels are significantly higher in cancer patients than in healthy controls, underscoring its value as a diagnostic and prognostic tumour marker. The low variability within each group and the distinct difference between groups highlight the reliability of CEA measurements. While CEA alone should not be the sole basis for diagnosis, its elevation strongly

suggests malignancy when interpreted with clinical findings. Monitoring CEA levels can aid in assessing disease progression and treatment response. Overall, CEA serves as an important adjunct in cancer detection and management, enhancing clinical decision-making. Further studies with larger cohorts are recommended to validate these findings.

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Conflict of Interest

We declare that there is no conflict of interest regarding the publication of this research. All experiments were conducted independently without any financial or personal relationships that could influence the outcomes.

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