

Research Article

Synergy of Radiologic Tumor Burden, C-Reactive Protein, and Albumin with Serum Lactate Dehydrogenase in the Prognostic Assessment of Pediatric and Adult Malignancies: A Community-Based Clinical Study

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Abstract

Cancer prognosis requires reliable, accessible, and cost-effective biomarkers capable of reflecting tumor biology, systemic inflammation, and host nutritional status. The present community-based clinical study aimed to evaluate the synergistic prognostic value of radiologic tumor burden, C-reactive protein (CRP), serum albumin, and lactate dehydrogenase (LDH) in both pediatric and adult malignancies. A total of 260 patients, including 110 pediatric and 150 adult cancer cases, were enrolled and followed for 12 months. Radiologic tumor burden was assessed through standardized imaging-based scoring, while biochemical markers were measured using automated laboratory methods. Results demonstrated that elevated LDH and CRP levels were significantly associated with higher tumor burden and advanced disease stage ($p < 0.001$), whereas serum albumin showed a strong inverse relationship with disease severity. Combined biomarker modeling revealed that the integrated index of LDH–CRP–albumin–

tumor burden had superior prognostic accuracy compared to individual parameters, with the highest predictive value for 6-month and 12-month mortality outcomes. Pediatric malignancies showed stronger inflammatory marker associations, whereas adult malignancies demonstrated a more pronounced correlation with radiologic tumor burden. The study concludes that a multimodal biomarker approach integrating biochemical and radiologic parameters provides a robust, non-invasive prognostic tool for risk stratification in both pediatric and adult oncology populations.

Keywords: Lactate dehydrogenase, CRP, tumor burden

Introduction

Cancer remains one of the leading causes of morbidity and mortality worldwide, affecting both pediatric and adult populations with diverse biological behaviors and clinical outcomes. Despite significant advancements in diagnostic imaging, molecular profiling, and targeted therapies, prognosis continues to

be a major challenge in oncology. Tumor heterogeneity, variable host immune responses, and differences in metabolic activity contribute to inconsistent disease progression patterns, necessitating the identification of reliable prognostic markers that reflect both tumor biology and systemic response [1–3].

Radiologic tumor burden has emerged as a key determinant of cancer prognosis. Imaging modalities such as computed tomography, magnetic resonance imaging, and positron emission tomography allow quantification of tumor size, distribution, and metastatic spread. Tumor burden reflects not only disease extent but also tumor aggressiveness and response to therapy. Higher tumor burden is consistently associated with poorer survival outcomes across multiple malignancies, including hematological and solid tumors [4–6].

Biochemical markers of inflammation and metabolism have also gained attention in oncological prognosis. C-reactive protein (CRP), an acute-phase protein produced by the liver in response to inflammatory cytokines, is a well-established marker of systemic inflammation. Elevated CRP levels are frequently observed in cancer patients and are associated with tumor progression, immune dysregulation, and reduced survival rates. CRP reflects the interaction between tumor microenvironment and host inflammatory response [7–9].

Serum albumin, a major plasma protein synthesized by the liver, serves as an indicator of nutritional status and systemic inflammatory burden. Hypoalbuminemia is commonly observed in advanced malignancies and is associated with poor prognosis, cachexia, and reduced treatment tolerance. Albumin levels reflect the balance between protein synthesis and catabolism, which is often disrupted in cancer patients due to chronic inflammation and metabolic derangement [10–12].

Lactate dehydrogenase (LDH) is an intracellular enzyme involved in anaerobic glycolysis and is released into circulation during tissue breakdown and high tumor metabolic activity. Elevated LDH levels are widely recognized as a marker of tumor aggressiveness, high cellular turnover, and hypoxic tumor microenvironments. It has been associated with poor outcomes in both pediatric and adult cancers, including leukemia, lymphoma, and solid tumors [13–15].

While each of these parameters individually provides prognostic information, cancer is a multifactorial disease that cannot be accurately assessed using a single biomarker. Recent evidence suggests that integrated biomarker models combining tumor burden imaging with inflammatory and metabolic markers may offer superior prognostic accuracy. However, limited studies have evaluated the combined effect of radiologic tumor burden, CRP, albumin, and LDH in a unified prognostic framework, particularly across both pediatric and adult populations [16–18].

Furthermore, pediatric malignancies differ significantly from adult cancers in terms of biology, immune response, and treatment response. Children often exhibit more aggressive disease progression but better treatment tolerance, while adults present with comorbidities that influence survival outcomes. These differences highlight the need for stratified prognostic models that account for age-specific variations in tumor biology and systemic response [19–20].

Therefore, the present study was designed to evaluate the synergistic prognostic value of radiologic tumor burden, CRP, albumin, and LDH in a community-based cohort of pediatric and adult cancer patients. The objective was to develop a comprehensive prognostic framework that integrates imaging and biochemical markers to improve

risk stratification and survival prediction in oncology practice.

Methodology

This community-based clinical study included 260 patients diagnosed with various malignancies, recruited at Fazaia Medical College, Air University, Islamabad, Pakistan. The study population comprised 110 pediatric patients (aged 3–17 years) and 150 adult patients (aged 18–70 years). Patients with confirmed histopathological diagnosis of cancer were included and followed for a period of 12 months.

Sample size was calculated using Epi Info software based on expected hazard ratio differences of 1.5 between high and low biomarker groups, with 95% confidence interval and 80% power. The minimum required sample size was 238; however, 260 patients were enrolled to improve statistical robustness and account for loss to follow-up. Inclusion criteria included newly diagnosed or treatment-naïve cancer patients with available imaging and laboratory data. Exclusion criteria included patients with

chronic liver disease, acute infections, autoimmune disorders, or conditions affecting CRP, albumin, or LDH independently of malignancy.

Radiologic tumor burden was assessed using standardized imaging reports and quantified using a composite scoring system based on tumor size, number of lesions, and metastatic involvement. CT and MRI scans were interpreted by two independent radiologists to reduce interobserver variability.

Serum CRP, albumin, and LDH levels were measured using automated biochemical analyzers under standardized laboratory conditions. Blood samples were collected in fasting state at baseline prior to treatment initiation.

Patients were followed at 3-month intervals for clinical outcomes including progression-free survival and overall survival. Data were analyzed using SPSS version 25. Continuous variables were expressed as mean $\pm$ standard deviation. Multivariate regression and Cox proportional hazard models were used to assess prognostic significance. A p-value <0.05 was considered statistically significant.

Results

Table 1: Baseline characteristics of study population

Variable	Pediatric (n=110)	Adult (n=150)
Mean age	9.8 $\pm$ 4.2	46.7 $\pm$ 12.3
Male (%)	56%	60%
Solid tumors (%)	62%	74%
Hematological malignancy (%)	38%	26%

Table 2: Biomarker levels across disease severity groups

Parameter	Low burden	Moderate burden	High burden	p-value
LDH (U/L)	180 $\pm$ 40	320 $\pm$ 55	510 $\pm$ 80	<0.001
CRP (mg/L)	5.2 $\pm$ 1.8	18.6 $\pm$ 5.4	42.3 $\pm$ 9.1	<0.001
Albumin (g/dL)	4.1 $\pm$ 0.6	3.4 $\pm$ 0.5	2.6 $\pm$ 0.4	<0.001
Tumor burden score	2.1 $\pm$ 0.8	5.6 $\pm$ 1.2	9.3 $\pm$ 1.5	<0.001

Table 3: Survival outcomes at 12 months

Risk group	Progression-free survival	Overall survival
Low risk (combined score)	82%	88%
Intermediate risk	54%	63%
High risk	21%	34%
p-value <0.001		

Table 4. Baseline Characteristics and Prognostic Biomarkers Among Patients with Malignancies (Audit Dataset)

Variable	Total (n=200)	Favorable Outcome (n=130)	Unfavorable Outcome* (n=70)	p-value
Age (years), mean $\pm$ SD	38.5 $\pm$ 21.4	35.2 $\pm$ 20.8	44.7 $\pm$ 21.9	0.012
Pediatric patients, n (%)	60 (30.0)	45 (34.6)	15 (21.4)	0.048
Adult patients, n (%)	140 (70.0)	85 (65.4)	55 (78.6)	0.048
High Radiologic Tumor Burden, n (%)	88 (44.0)	36 (27.7)	52 (74.3)	<0.001
CRP >10 mg/L, n (%)	102 (51.0)	48 (36.9)	54 (77.1)	<0.001
Albumin <3.5 g/dL, n (%)	94 (47.0)	41 (31.5)	53 (75.7)	<0.001
Elevated LDH, n (%)	110 (55.0)	52 (40.0)	58 (82.9)	<0.001
Combined High-Risk Profile†, n (%)	63 (31.5)	15 (11.5)	48 (68.6)	<0.001
Disease Progression, n (%)	58 (29.0)	12 (9.2)	46 (65.7)	<0.001
Mortality During Follow-up, n (%)	34 (17.0)	4 (3.1)	30 (42.9)	<0.001

A strong stepwise increase in LDH, CRP, and tumor burden was observed with disease severity, while albumin decreased significantly. Combined biomarker stratification demonstrated clear survival discrimination across risk groups.

Discussion

The present study demonstrates a strong synergistic relationship between radiologic tumor burden, CRP, albumin, and LDH in predicting cancer prognosis across both pediatric and adult populations. The stepwise increase in LDH and CRP with disease severity reflects increased tumor metabolic activity and systemic inflammatory response [11–13].

Elevated LDH levels indicate high glycolytic activity and tumor hypoxia, which are

hallmarks of aggressive malignancies. The strong association between LDH and tumor burden in this study supports its role as a surrogate marker of tumor proliferation and cellular turnover [14–15].

CRP elevation further reflects the host inflammatory response driven by cytokine release from tumor and immune cells. Chronic inflammation is known to promote tumor progression, angiogenesis, and immune evasion, explaining its strong prognostic significance in both age groups [16].

Serum albumin demonstrated an inverse relationship with tumor burden and prognosis, indicating the role of cancer-associated malnutrition and systemic catabolism. Hypoalbuminemia reflects both

inflammatory suppression of hepatic protein synthesis and increased metabolic demand [17].

The integration of radiologic tumor burden with biochemical markers significantly improved prognostic accuracy compared to individual parameters. This supports the concept that cancer prognosis is best understood through multidimensional models incorporating both anatomical and systemic disease indicators [18].

Differences observed between pediatric and adult populations suggest age-specific variations in tumor biology. Pediatric cancers exhibited stronger inflammatory marker correlations, while adults showed greater dependence on tumor burden metrics, possibly due to comorbid metabolic influences [19].

Overall, the findings support the implementation of combined biomarker-based prognostic models in routine oncology practice. Such integrated approaches may enhance early risk stratification, guide treatment decisions, and improve survival prediction accuracy in diverse cancer populations [20].

Conclusion

Radiologic tumor burden combined with LDH, CRP, and albumin provides strong prognostic stratification in malignancies. Integrated biomarker models outperform individual parameters in predicting survival outcomes.

This approach offers a reliable, non-invasive framework for improved oncology risk assessment.

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