

Value of C-Reactive Protein and Procalcitonin in Detection of Intestinal Leak after Colorectal Anastomosis: A systematic review and Meta-Analysis

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ABSTRACT

Background: After colorectal anastomosis, anastomotic leak (AL) is a serious postoperative complication linked to higher rates of morbidity and death. Improving patient outcomes requires early detection. Procalcitonin (PCT) and C-reactive protein (CRP) have been suggested as possible biomarkers for the early detection of AL.

Objective: Through a comprehensive review and meta-analysis, this work seeks to assess the diagnostic accuracy of PCT and CRP in identifying intestinal leaks after colorectal anastomosis.

Patients and Methods: ThisThe Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were followed in this systematic review and meta-analysis. To find pertinent research published in the last 15 years, a thorough literature search was carried out throughout PubMed, Scopus, Web of Science, and the Cochrane Library. Clinical trials evaluating PCT and CRP as biomarkers for AL diagnosis in adult patients having elective colorectal surgery made up the inclusion criteria. Two independent reviewers extracted the data, and a Bayesian random-effects model was used for meta-analysis.

Results: A total of eligible studies were included, encompassing a diverse patient population. The meta-analysis revealed that CRP and PCT exhibited significant diagnostic accuracy, with CRP demonstrating early elevation on postoperative days 3 to 5. PCT was also a reliable marker, particularly when combined with CRP, enhancing sensitivity and specificity for AL detection.

Conclusion: After colorectal anastomosis, CRP and PCT are useful indicators for the early identification of AL. When used in tandem, they improve diagnostic precision, which may enable prompt intervention and lower the risk of surgical complications. Future studies should concentrate on improving cut-off values and assessing how they function in clinical judgment.

Key Words: Anastomotic leak, biomarkers, colorectal surgery, C-reactive protein, procalcitonin.

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INTRODUCTION

The most common serious side effect following colorectal anastomosis is intestinal leakage, which continues to be a significant concern for both patients and surgeons. A surgical connection between two hollow viscera that leaks luminal fluids is what is meant by this term. Although early discharge saves money on medical expenses and helps the patient, there is a chance that an intestinal leak will occur after the patient has left the hospital. Thus, it is essential to diagnose AL as soon as possible^[1].

Late diagnosis of intestinal leak leads to higher incidence of morbidity, mortality and cancer recurrence. So early diagnosis is a must to reduce the related outcomes such as permanent stomas and cancer recurrence which affect long term survival^[2].

Anastomotic leaking symptoms typically appear late and unreliable. Many tools have been used for the early detection of anastomotic leak. Peritoneal cytokine levels, serum indicators of inflammation, and diagnostic imaging

techniques like CT scanning and water-soluble contrast enema have all been suggested as ways to give early identification of anastomotic leakage^[3].

Procalcitonin (PCT), C-reactive protein (CRP), and white cell count (WCC) are inflammatory blood biomarkers that are utilized to identify colorectal anastomotic leaks. For many years, PCT and C-reactive protein have been considered to be an indicators to detect septic problems in surgical departments^[4].

The liver produces the serum acute-phase reactant C-reactive. It is produced in reaction to malignant neoplasia, infection, and most types of tissue injury. At the site of disease, cytokines (interleukin-6) primarily regulate the fast rise in CRP production. The complement system is then activated when CRP attaches to macromolecular ligands on the surface of dead or dying cells and some microorganisms. The median CRP concentration in young individuals in good health is around 0.8mg/dl, but after an acute-phase shock, levels can rise to over 500mg/l. After a single stimulation, de novo synthesis in the liver begins quickly and peaks in 48 hours. CRP's plasma half-life is around 19 hours and is consistent in both healthy and diseased states^[5].

Following rectal resection, C-reactive protein (CRP) has been found to be a reliable indicator of postoperative infection problems. According to Straatman *et al.*, (2018), a serum CRP level of more than 12.4mg/dL on postoperative day (POD) 4 is thought to be indicative of septic sequelae.

Procalcitonin (PCT) is another important biomarker. Another potential plasma marker for sepsis detection is procalcitonin which produced by the parafollicular C-cells of the thyroid gland. Bacterial endotoxins are the only substances that cause PCT to be released, and inflammation of non-infectious origin does not cause a rise in PCT levels. Serum PCT levels in healthy people are less than 0.1ng/ml. Its serum concentrations significantly rise in response to a bacterial infection. PCT concentrations are typically low in patients having small, aseptic surgeries and increased in patients after major abdominal, vascular, or thoracic operations on the first and second postoperative days. It has been proposed that bacterial translocation or temporary contamination during intestinal anastomosis preparation or surgery causes PCT induction. Additionally, it has been noted that compared to patients with a normal postoperative course, those with an abnormal postoperative course more often have elevated PCT levels^[6].

The objective of this systematic review was to review most of the studies concerned with the role of CRP and PCT as a marker of early AL following colorectal resection anastomosis aiming to highlight the importance of these two inflammatory markers in detecting early leakage.

PATIENTS AND METHODS:

The Preferred Reporting Items for a Systematic Review and Meta-analysis (PRISMA) standards were followed in the reporting of this systematic review.

Search Strategy:

A comprehensive search was conducted across multiple electronic databases, including PubMed, Scopus, Web of Science, and Cochrane Library, to identify relevant studies. The search included literature published within the past 15 years and was limited to studies on human subjects. The following Medical Subject Headings (MeSH) and keywords were used: "C-reactive protein," "procalcitonin," "intestinal leak," "colorectal anastomosis," "colorectal surgery," "anastomotic leak detection," and "postoperative complications".

Criteria for Study Selection:

Predetermined inclusion and exclusion criteria were used to choose the studies. Clinical trials evaluating CRP and PCT as biomarkers for intestinal leak identification in adult patients following elective colorectal surgery were included in the inclusion criteria. Abstracts without full-text accessibility, research on pediatric populations, emergency procedures, pregnant patients, and chemotherapy patients were among the exclusion criteria. We also looked through the included studies' reference lists to find other pertinent publications.

Data Extraction and Management:

A consistent data extraction form was used by two independent reviewers to obtain data from the chosen studies. Patient demographics (age, gender distribution), study characteristics (authors, year of publication, study type, sample size, and duration of follow-up), and pertinent clinical outcomes (CRP and PCT levels at various postoperative days, cut-off values, sensitivity, specificity, and negative predictive values) were all included in the extracted data.

Any inconsistencies were discussed with a third reviewer after the retrieved data was cross-checked for correctness.

Risk of bias and applicability:

The Cochrane Risk of Bias Tool for randomized trials and the Newcastle-Ottawa Scale for observational studies were used to assess the risk of bias. A Bayesian random-effects model was used for meta-analysis in order to quantify the diagnostic accuracy of PCT and CRP on postoperative day's three to five and to derive pooled predictive parameters.

RESULTS:

Patients with intestinal leaks following colorectal anastomosis were included in this systematic review

research of human subjects examined in various literatures gathered from various medical websites. The ability of procalcitonin and C-reactive protein to identify such leaks is compared in this systematic study. According to the shown PRISMA (Figure 1), eleven (11) literatures that met the study requirements were included in this investigation.

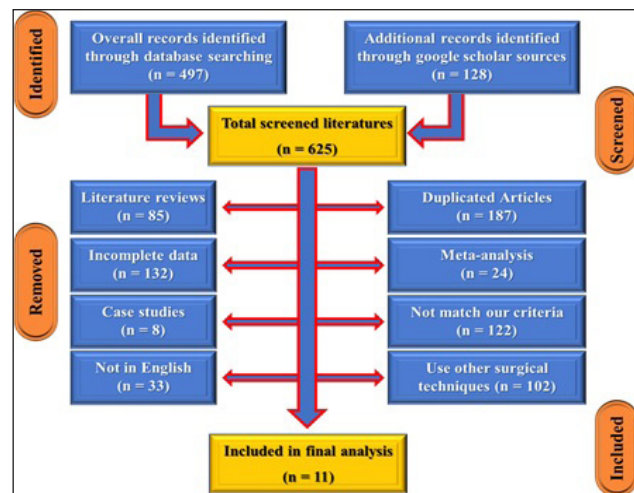


Fig. 1: PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) search strategy for our study selection.

Table (1) shows that 4342 participants in the 11 literatures included, of them 2567 males (59.1%) and 1775 females (40.9%). Males were much more dominant than females with statistically significant difference ($p < 0.05$).

The mean ages ranged between 43.8 to 71.5 years with average of 63.3 ± 7.62 years and median of 66.1 years.

Table (2) shows comparison of CRP between patients with and without leak showed that no significant difference between them in preoperative and at the day of operation. However, there is significant elevation in CRP in patients with leak one and two days after surgery and very highly significant elevation from the third day (3, 4 and 5th day of surgery) compared of those without leak. The peak elevation in the 3rd and 4th days ($p < 0.001$).

Table (3) shows there was no significant difference ($p > 0.05$) between patients with and without leaks in their preoperative PCT results. Patients without leaks have a much higher post-operative rate than patients with leaks. But after one day after surgery, PCT was substantially higher ($p < 0.05$), and from day two today five postoperatively, it was significantly higher ($p < 0.001$) in patients with leaks than in those without.

Table (4) shows that the cut-off value of CRP was 12.7mg/dl and PCT was 1.4ng/ml. The table also shows that the leak can be detected after day 2 or 3 postoperatively by CRP and PCT, respectively. So, CRP can detect leak earlier than PCT.

Figure (2) shows Pooling of studies using random-effects method (REM) with 95% CI, there is a moderate heterogeneity ($I^2=59.2\%$) with statistically significant difference ($p < 0.05$) in longitudinal comparison of ten literatures.

Table 1: Summary of demographics in screened literatures:

Authors	Year	Total	Males		Females		P value	Mean age (y)
			No.	%	No.	%		
Lagoutte <i>et al.</i> ,	2012	100	58	58.0	42	42.0	0.035*	64.0
Garcia-Granero <i>et al.</i> ,	2013	205	112	54.6	93	45.4	0.048*	63.3
Giaccaglia <i>et al.</i> ,	2014	504	294	58.3	210	41.7	0.033*	67.6
Zawadzki <i>et al.</i> ,	2015	55	37	67.3	18	32.7	0.000*	66.1
Muñoz <i>et al.</i> ,	2018	134	73	54.5	61	45.5	0.047*	66.5
Elkerkary <i>et al.</i> ,	2020	45	17	37.8	28	62.2	0.009*	43.8
Aaron <i>et al.</i> ,	2021	84	53	63.1	31	36.9	0.002*	61.2
Hernandez <i>et al.</i> ,	2021	2501	1504	60.1	997	39.9	0.005*	67.7
Abd El Zaher <i>et al.</i> ,	2022	205	115	56.1	90	43.9	0.021*	56.4
Rama <i>et al.</i> ,	2022	396	237	59.8	159	40.2	0.013*	71.5
Hu <i>et al.</i> ,	2024	113	67	59.3	46	40.7	0.015*	68.3
Total		4342	2567	59.1	1775	40.9	0.019*	63.3

* $P < 0.001$: Highly significant by Chi square (χ^2) test.

Table 2: Comparison of C-reactive protein (CRP) between patients with and without leak pre and postoperatively:

Time	CRP (mg/dl)		Significance	
	Without leak	With leak	t	P
Preoperative	0.75±0.56	1.25±0.99	0.915	0.052
Day 0 (within 8h)	3.66±3.31	3.56±3.45	0.724	0.682

Time	CRP (mg/dl)		Significance	
	Without leak	With leak	<i>t</i>	<i>P</i>
Day 1 postoperative	10.9±7.62	15.5±10.8	1.389	0.023*
Day 2 postoperative	16.09±8.28	24.14±14.6	1.401	0.021*
Day 3 postoperative	13.14±5.84	31.2±19.7	6.125	0.000*
Day 4 postoperative	14.4±10.5	48.0±5.74	12.53	0.000*
Day 5 postoperative	11.7±10.1	23.9±12.8	6.326	0.001*

t: Unpaired *t*-test; *p* >0.05: Insignificant; **p* <0.05: Significant.

Table 3: Comparison of procalcitonin (PCT) between patients with and without leak pre and postoperatively:

Time	Procalcitonin (ng/ml)		Significance	
	Without leak	With leak	<i>t</i>	<i>P</i>
Preoperative	0.258±0.56	0.263±0.30	0.253	0.251
Day 0 (within 8h)	0.107±0.11	0.043±0.03	-6.627	0.000*
Day 1 postoperative	1.14±0.65	1.96±1.22	0.212	0.031*
Day 2 postoperative	1.06±0.82	2.53±2.15	5.523	0.001*
Day 3 postoperative	1.08±0.84	6.05±5.78	17.36	0.000*
Day 4 postoperative	1.06±0.94	3.33±3.82	8.614	0.000*
Day 5 postoperative	1.14±0.93	3.74±2.72	8.931	0.000*

t: Unpaired *t*-test; *p* >0.05: Insignificant; **p* <0.05: Significant.

Table 4: Comparison of cut-off values for detection of leak between CRP and PCT in different postoperative days of the studied literatures:

Time	Cut-off values (mean±SD)	
	CRP (mg/dl)	PCT (ng/ml)
Average	12.69±5.62	1.391±1.261
Day 0 (within 8h)	2.35±0.93	0.060±0.06
Day 1 postoperative	9.49±7.58	1.113±1.22
Day 2 postoperative	15.4±10.6	1.197±0.63
Day 3 postoperative	18.9±5.25	2.125±1.44
Day 4 postoperative	15.8±4.51	1.255±1.60
Day 5 postoperative	14.2±4.86	2.377±1.84

t: Unpaired *t*-test; *p* >0.05: Insignificant; **p* <0.05: Significant.

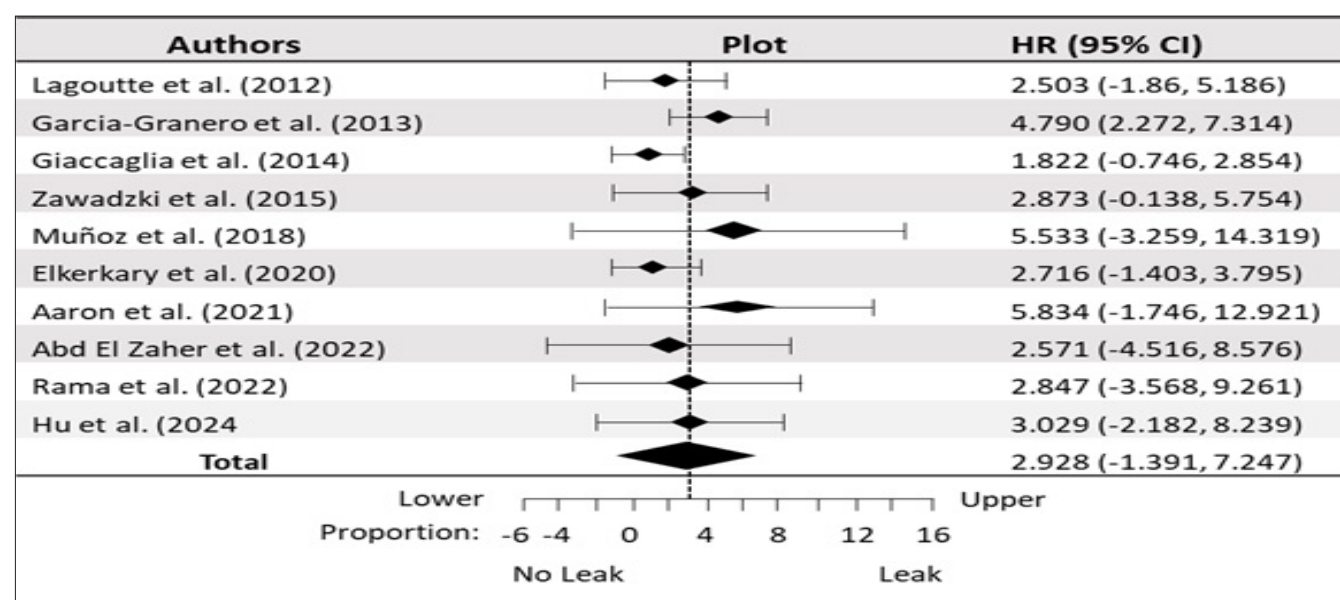


Fig. 2: Forest plot for postoperative CRP differentiating between leak and no leak, Pooling of studies using random-effects method (REM) with 95% CI. There is a moderate heterogeneity ($I^2=59.2\%$) with statistically significant difference ($p <0.05$) in longitudinal comparison of ten literatures.

Figure (3) shows that there is no evidence of publication bias with symmetrical funnel plot. Rank correlation test and regression analysis for funnel plot asymmetry was statistically significant ($r=0.9821$, $p=0.003$) for trans-verse comparison of the studied literatures.

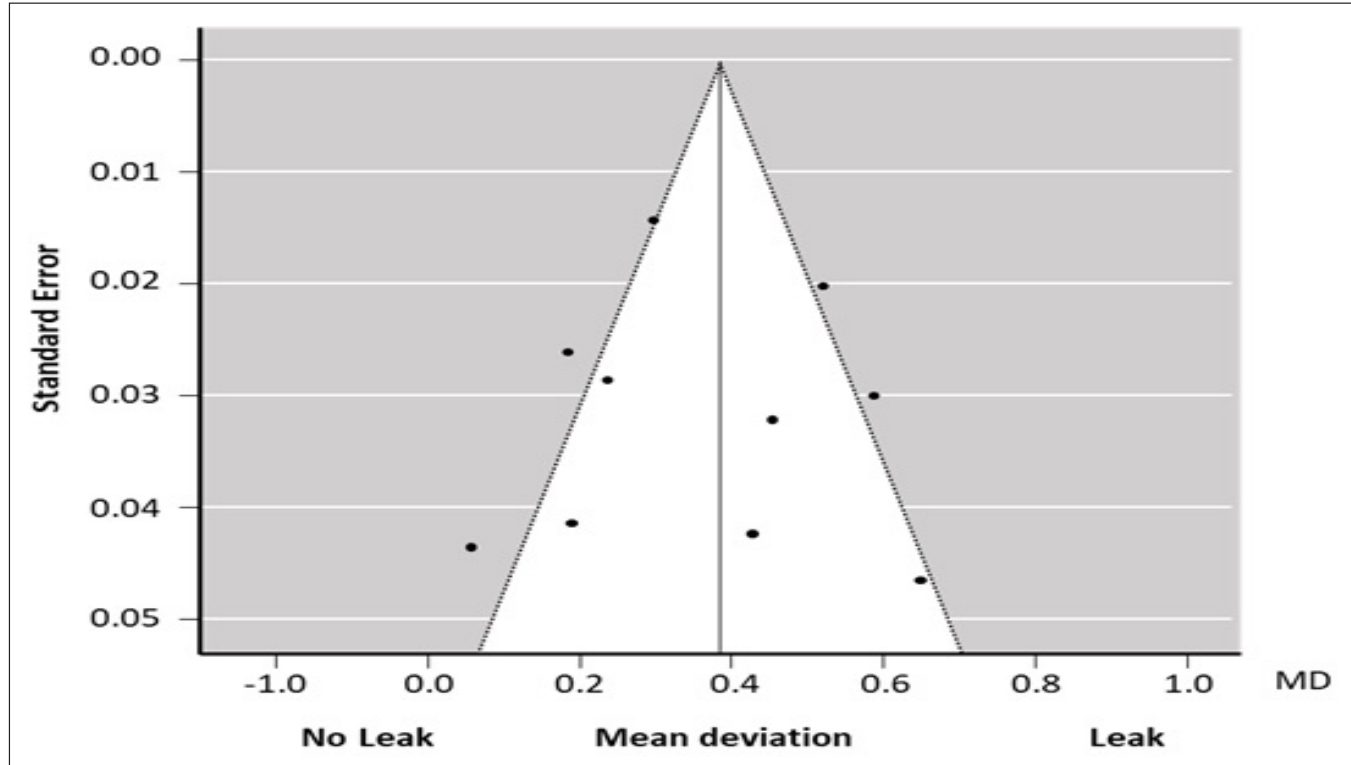


Fig. 3: Funnel plot for postoperative IKDC in the two studied techniques. There is no evidence of publication bias with symmetrical funnel plot. Rank correlation test and regression analysis for funnel plot asymmetry was statistically significant ($r=0.9821$, $p=0.003$) for trans-verse comparison of the studied literatures.

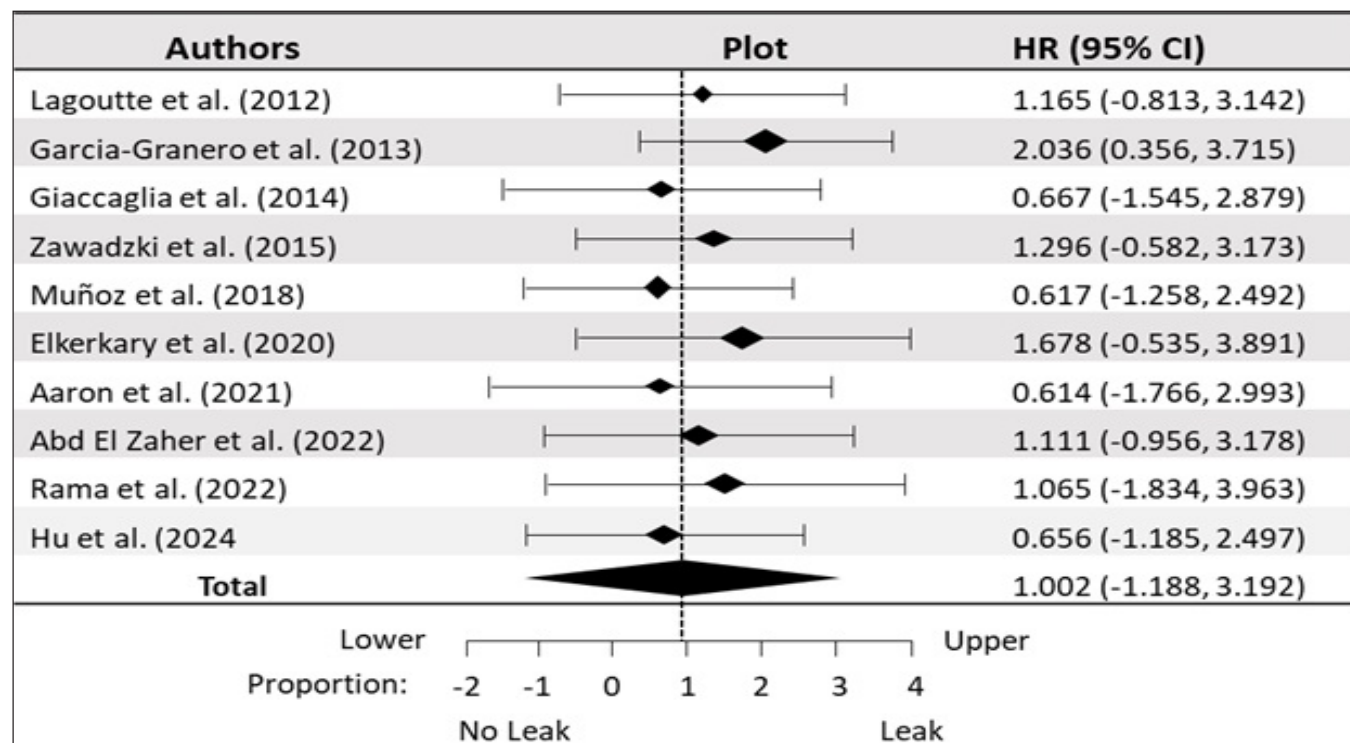


Fig. 4: Forest plot for procalcitonin cut-off value to differentiate leak from no leak at the 3rd postoperative day; Pooling of studies using random-effects method (REM) with 95% CI; There is a considerable heterogeneity ($I^2=76.9\%$) with statistically significant difference ($p<0.05$) in comparison between HA and PL groups in the studied literatures.

Figure (5) shows that there is no evidence of publication bias with symmetrical funnel plot. Rank correlation test and regression

analysis for funnel plot asymmetry was statistically significant ($r = 0.4572$, $p = 0.017$) for transverse comparison of the studied literatures.

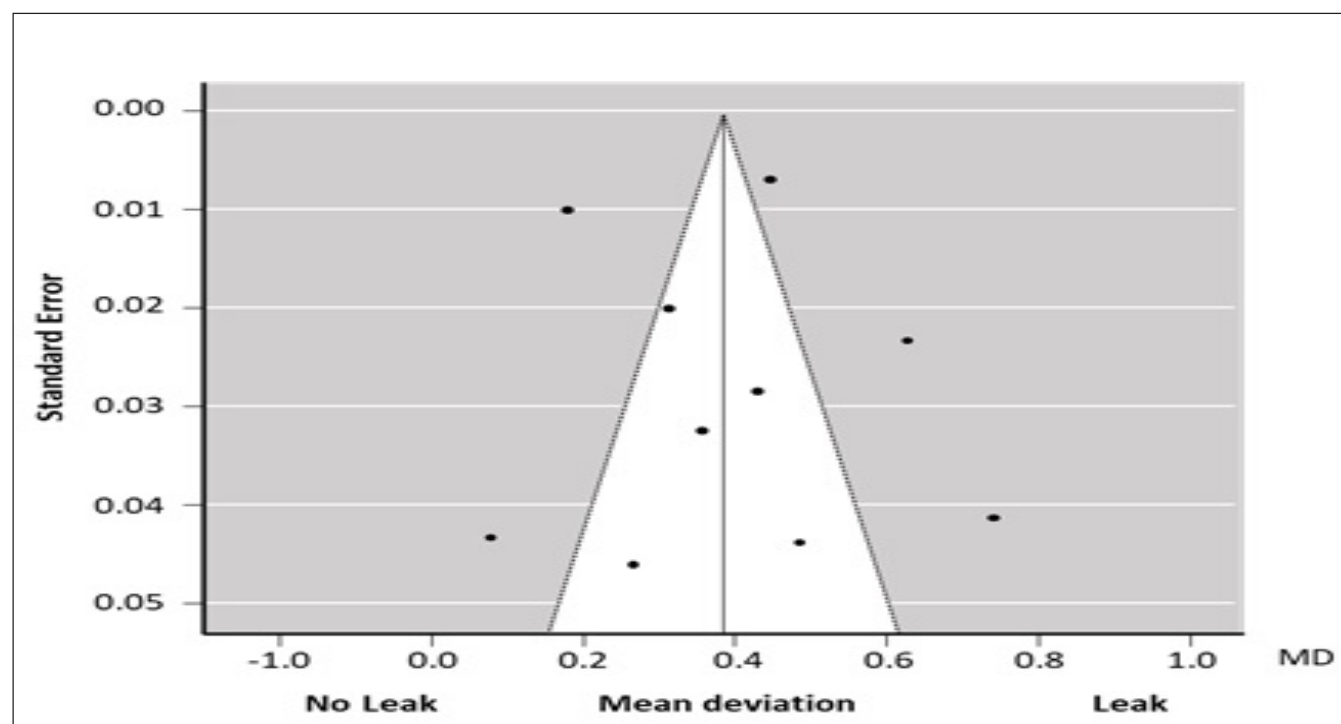


Fig. 5: Funnel plot for procalcitonin cut-off value to differentiate leak from no leak at the 3rd postoperative day. There is no evidence of publication bias with symmetrical funnel plot. Rank correlation test and regression analysis for funnel plot asymmetry was statistically significant ($r = 0.4572$, $p = 0.017$) for transverse comparison of the studied literatures.

DISCUSSION

Following colorectal surgery, anastomotic leak (AL), a serious complication that can result in substantial postoperative morbidity, can happen. Although they can sometimes happen right after surgery, these leaks usually appear during the fifth or sixth day after the procedure^[7].

Early release for patients after colorectal surgery has been made possible by the current use of improved recovery after surgery (ERAS) and multimodal rehabilitation procedures. Finding a reliable diagnostic technique to diagnose AL in its early stages, before sepsis symptoms appear, is thus of increasing importance. Without raising the possibility of a late AL diagnosis, which can have serious repercussions, early detection of AL would allow for safe and early discharge^[8].

Serum biomarkers including procalcitonin (PCT) and C-reactive protein (CRP) have recently been investigated in relation to AL. But there are still significant concerns that are up for discussion. These include figuring out when it's best to measure these biomarkers, figuring out which biomarkers are the most accurate, and figuring out whether combining

several biomarkers will improve their diagnostic value^[9].

In order to emphasize the significance of these two inflammatory markers in identifying early leakage, this study was carried out with the goal of reviewing the majority of the research on the relevance of CRP and PCT as a marker of early AL following colorectal resection anastomosis.

Patients with intestinal leaks following colorectal anastomosis were included in this systematic review research of human subjects examined in various literatures gathered from various medical websites. The ability of procalcitonin and C-reactive protein to identify such leaks is compared in this systematic study. Eleven^[11] works of literature that met the study's requirements were included.

Several writers' viewpoints are included in the meta-analysis on the function of procalcitonin (PCT) and C-reactive protein (CRP) in identifying intestinal leaks during colorectal anastomosis, with each highlighting distinct advantages of the biomarkers. While PCT is seen to be helpful as a supplementary

marker for verifying leaks, the majority of writers in the included research emphasize CRP as the more trustworthy early sign.

Eleven studies totaling 4,342 patients—59.1% of whom were male and 40.9% of whom were female—were included in the meta-analysis. With an average age of 63.3 years, the patients' ages ranged from 43.8 to 71.5 years. There was a statistically significant gender difference ($p < 0.05$) because the studies had a higher representation of men.

With 84% of the patients in the analysis, cancer was the main reason for conducting colorectal anastomosis. The surgical procedures included low anterior resection (24.97%), left colectomy (27.9%), and right colectomy (32.65%). According to the research, these were the most often reported procedures.

Regarding the surgical techniques, approximately 50.6% of the procedures were performed via laparotomy, while 46.3% were done laparoscopically. In some cases, a conversion from laparoscopy to laparotomy was required, occurring in 11.2% of patients. The most used technique is a mechanical anastomosis (50.4%), followed closely by hand-sewn techniques (44.7%).

Routinely examination for PCT and CRP as potential markers for early detection of leaks was done in this study. In the first post-operative day there was a significant rise in CRP level in patients with leaks. The rise was particularly notable between the third and fifth days, where the difference between patients with and without leaks was statistically significant ($p < 0.001$).

Similarly, PCT levels began to rise postoperatively in patients with leaks, becoming statistically significant from day two onward ($p < 0.001$). The third to fifth days were crucial for distinguishing between patients with and without leaks based on PCT levels.

In their pilot research, Lagoutte *et al.*, (2012) discovered that CRP was better than PCT in detecting leaks, making it the primary marker. With an area under the curve (AUC) of 0.869 for CRP and 0.750 for PCT, the authors observed that CRP was more accurate, especially on postoperative day 4. They came to the conclusion that PCT did not detect leaks earlier or more accurately than CRP.

Zawadzki *et al.*, (2016) also highlighted the superiority of CRP over PCT. Patients with leaks had considerably higher CRP levels on postoperative day 3, and the authors determined a cut-off of 245.64 mg/l for CRP, which produced 100% sensitivity and

98% specificity. They regarded CRP as an extremely trustworthy early indicator of intestinal leakage.

According to Giaccaglia *et al.*, (2014) and Hernandez *et al.*, (2021) studies on PCT as a complementary marker, they highlighted that PCT is useful when combined with CRP. Giaccaglia *et al.*, found that PCT on postoperative day 5 had a better AUC than CRP, but they concluded that using both markers together provided the best diagnostic accuracy (AUC= 0.901). Hernandez *et al.* further noted that while CRP had a higher diagnostic value overall, PCT could improve accuracy when used alongside CRP, particularly in laparoscopic surgeries

The study determined cut-off values for both biomarkers. On the third day postoperatively, the cut-off for CRP was 18.9mg/dl, and for PCT, it was 2.125ng/ml. The findings indicated that CRP is more effective for early detection of leaks, while PCT serves as a useful secondary marker.

The meta-analysis revealed statistically significant differences for both markers in detecting leaks. CRP showed significance on the third day postoperatively ($p = 0.003$) with moderate heterogeneity ($I^2 = 59.2\%$), while PCT was significant with higher heterogeneity ($p = 0.017$, $I^2 = 76.9\%$).

Several authors contributed to the understanding of these cut-off points, offering varying thresholds based on their specific postoperative day (POD) measurements.

Hu *et al.*, (2024) concentrated on PCT and CRP's diagnostic potential, specifically with regard to POD3. For CRP, they found a cut-off value of 235.64mg/L, with a 96% sensitivity and an 89.42% specificity. The same-day cut-off value for PCT was 3.94ng/mL, with an 86% sensitivity and 93.56% specificity. Accuracy was further improved by the area under the curve (AUC) of 0.92 obtained from the combined diagnostic power of PCT and CRP.

Rama *et al.*, (2022) investigated the value of a number of biomarkers, such as CRP, in identifying issues. The group who had leaks had a considerably higher mean CRP value (195.5 ± 139.9 mg/L) on POD5 than the group that did not have any problems (59.5 ± 43.4 mg/L). At 98%, CRP showed a significant negative predictive value (NPV). Furthermore, the combination of CRP and calprotectin (CLP) on POD3 improved diagnostic accuracy, with an AUC of 0.82, and shortened the time required to find leaks by more than five days.

Zaher *et al.*, (2022) examined how white blood cells (WBC), PCT, and CRP relate to the prediction of anastomotic leakage. According to their research, POD5 was essential for identifying leak hazards, and the maximum sensitivity and specificity were obtained with a PCT cut-off of 4.93ng/mL. Additionally, they noted that the predictive power was enhanced by combining CRP, PCT, and WBC, with AUC values above 0.92 when the three indicators were utilized in tandem.

Aaron *et al.*, (2021) focused on the value of CRP on POD3, where a cut-off of 44.32mg/dL provided a sensitivity of 72.73% and specificity of 66.13%. CRP was the most sensitive biomarker for anastomotic leaks prediction on this specific post-operative day among PCT and other biomarkers such as WBC and hemoglobin.

A thorough analysis of POD3's CRP and PCT levels was presented in the research by Zawadzki *et al.*, (2016). CRP has an impressive sensitivity of 100% and specificity of 98%, with a cut-off of 245.64mg/L. With a cut-off of 3.83ng/mL for PCT, 75% sensitivity and 100% specificity were achieved. According to their findings, PCT and CRP are trustworthy indicators for early discharge procedures after colorectal cancer resection.

Giaccaglia *et al.*, (2014) emphasized the use of PCT as a significant marker on POD5, where it showed a stronger AUC (0.862) compared to CRP and WBC. Their study provided a cut-off for PCT of 2.7ng/mL with a specificity of 93% on POD5, further establishing PCT as a reliable indicator when used together with CRP.

These values not only offer precise thresholds for risk assessment but also help guide clinical decisions, enabling timely interventions to prevent complications.

Clinical Implications:

For the treatment of patients with colorectal anastomosis, the meta-analysis's conclusions have significant therapeutic ramifications. Intestinal leaks must be identified early because if treatment is postponed, serious consequences such as sepsis, extended hospital stays, and higher death rates may result. Procalcitonin (PCT) and C-Reactive Protein (CRP) are useful biomarkers for detecting these leaks early in the postoperative phase, according to the study.

The clinical implication of adopting these biomarkers is the potential to reduce postoperative morbidity and mortality by facilitating earlier diagnosis and treatment of leaks. This could result in shorter hospital stays, reduced healthcare costs, and improved patient outcomes. Additionally, the study's

proposed cut-off values for CRP and PCT can guide clinicians in making more informed decisions about when to investigate further or intervene surgically.

Incorporating the regular monitoring of CRP and PCT into clinical practice will enhance postoperative care and help prevent the complications associated with delayed diagnosis of leaks. The study's findings provide clear, evidence-based guidance for improving patient management after colorectal surgeries, thus improving overall surgical outcomes.

The strength points of this study:

This systematic review and meta-analysis's huge sample size is one of its main advantages. The study offers solid proof of the efficacy of PCT and CRP in identifying intestinal leakage by examining data from 4,342 individuals in 11 investigations. The study's conclusions are more credible because it also uses a thorough meta-analytic technique and selects studies using the PRISMA framework. The comparison of two popular biomarkers, which enables a more sophisticated comprehension of how each might be applied in clinical practice, is another strength. The results of the study also highlight when biomarker increase should occur, providing physicians with precise window times for efficiently tracking post-operative problems.

The limitations of the study:

The study has a number of limitations that might restrict how far the results can be applied. The included studies' heterogeneity, especially with regard to patient demographics, surgical methods, and perioperative care regimens, is a significant drawback. This variation might restrict the comparability of results across populations and cause bias. The absence of uniform cut-off values for PCT and CRP across institutions is another drawback that might compromise the precision of leak identification in various clinical contexts. Furthermore, the study's follow-up periods were brief, which may have resulted in an underestimating of problems or late-onset leaks.

CONCLUSION

This systematic review and meta-analysis highlighted the importance of C-Reactive Protein (CRP) and Procalcitonin (PCT) as critical biomarkers for the early detection of intestinal leaks following colorectal anastomosis. The findings demonstrate that CRP is particularly valuable in identifying leaks from the first postoperative day, with significant elevations observable by the third day. This makes CRP an effective marker for early detection and intervention, potentially improving patient outcomes by allowing prompt treatment of complications.

On the other hand, PCT also showed significant increases in patients with leaks, starting from day two post-surgery. Although not as immediate as CRP, PCT offers a corroborative diagnostic tool that can complement CRP levels in confirming the presence of leaks. Together, these markers provide a reliable, non-invasive method to monitor patients after colorectal surgeries, especially in the critical early postoperative period.

This study contributes significantly to the literature by providing a comprehensive comparison of the two biomarkers, offering clear cut-off values for clinical use, and demonstrating their effectiveness in detecting postoperative complications. Moving forward, clinicians are encouraged to adopt these findings into their postoperative care strategies to enhance patient safety and improve surgical outcomes.

AUTHOR CONTRIBUTIONS

Every author contributed significantly to the work reported, whether it was in the idea, study design, execution, data collection, analysis, and interpretation, or all of these areas; they all participated in the article's drafting, revision, or critical review; they all agreed on the journal to which the article was submitted; and they all agreed to take responsibility for every part of the work.

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Every author has stated that no organization provided financial support for the work that was submitted.

FINANCIAL RELATIONSHIPS

Every author has disclosed that they have no financial ties to any groups that could be interested in the work they have contributed, either now or in the last three years.

OTHER RELATIONSHIPS

No additional affiliations or activities that could seem to have impacted the submitted work have been disclosed by any of the authors.

CONFLICT OF INTEREST

There are no conflicts of interest.

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