

The diagnostic accuracy of serum lactate among patients with acute intestinal ischemia; A systematic review and meta-analysis

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ABSTRACT

Acute intestinal ischemia (AII) is a rare but severe medical emergency with high mortality, particularly when surgical intervention is delayed, and early diagnosis remains challenging due to the limitations of current diagnostic tools. This diagnostic test accuracy meta-analysis aimed to synthesise evidence on the diagnostic performance of serum lactate, D-lactate, and L-lactate levels for the early diagnosis of AII. A systematic search of 10 databases and registries, including PubMed, EMBASE, and ClinicalTrials.gov, was conducted up to 9 September 2024. Thirteen studies involving 1,978 patients (600 with AII) were included. The pooled sensitivity and specificity of serum lactate were 0.84 (95% CI: 0.81–0.87, $I^2=82.2\%$) and 0.60 (95% CI: 0.57–0.62, $I^2=96.5\%$), respectively, with an area under the curve (AUC) of 0.836. D-lactate demonstrated higher diagnostic performance, with pooled sensitivity and specificity of 0.94 (95% CI: 0.89–0.98, $I^2=70.5\%$) and 0.54 (95% CI: 0.46–0.61, $I^2=96.4\%$), respectively, and an AUC of 0.9015. L-lactate showed pooled sensitivity and specificity of 0.81 (95% CI: 0.72–0.87, $I^2=76.4\%$) and 0.68 (95% CI: 0.64–0.72, $I^2=96.9\%$), with an AUC of 0.8288, while plasma lactate exhibited sensitivity and specificity of 0.82 (95% CI: 0.78–0.86, $I^2=86.7\%$) and 0.56 (95% CI: 0.53–0.60, $I^2=97.3\%$), with an AUC of 0.8196. All included studies showed a low risk of applicability concerns regarding patient selection, though two had unclear risk concerning the index test. Significant heterogeneity was observed across studies. Overall, lactate levels—particularly D-lactate—demonstrate promise as biomarkers for early AII diagnosis. However, variability in specificity and study heterogeneity necessitate further validation before routine clinical application. Integrating lactate biomarkers with other diagnostic modalities may enhance early detection and improve patient outcomes. This review was registered in the Prospective Register of Systematic Reviews (PROSPERO) under CRD42024583735.

KEYWORDS: Ischemia; Lactate; Prediction; Diagnosis; Emergency Medicine.

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INTRODUCTION

Acute intestinal ischemia (AII) is a rare but a serious medical emergency associated with high mortality rate, of 67- 80%, when surgical intervention is delayed.¹ It can be categorised as small intestinal (mesenteric) or large intestinal (colonic) ischemia; and arises from vascular or non-vascular causes, with vascular origins including mesenteric arterial embolism, venous thrombosis, and non-occlusive ischemia.²⁻⁴ AII has a burden on the health system with emergency general surgery across the United States frequently performing procedures such as bowel resection, anastomosis, and lysis of peritoneal adhesions to manage it.⁵ Identifying AII in early reversible stages minimizes morbidities and mortality.⁶ However, despite its severity and impact on the health system, the prognosis for patients with AII remains poor, largely due to the persistent challenges of early diagnosis and timely surgical intervention. The classical signs of AII include abdominal pain, tachycardia, fever, and peritoneal irritation; however, these manifestations reflect advanced stages and are mostly unreliable for diagnosing AII at early reversible stages.^{7, 8} Current laboratory biomarkers including C-reactive protein, creatine kinase, and lactate dehydrogenase are non-specific for AII diagnosis while radiological tests although promising are limited by the varied AII causes.⁹ The ambiguous clinical presentation and the inaccurate diagnostic tools urgently necessitate more accurate diagnostic measures as delayed surgical interventions may lead to progressive extension of necrosis that requires large resections and subsequent poor outcomes.^{10, 11} Reliable and consistent biomarkers for the prediction of AII can contribute to better diagnosis. Serum lactate is a feasible and inexpensive biomarker commonly performed in the hypoperfusion status.^{12, 13} The lactate level in the peripheral blood may correspond to the severity of AII. D-lactate is produced only by colonic bacteria during bacterial fermentation. The normal mucosal barrier is disrupted during AII, resulting in increased permeability, allowing a large amount of D-lactate to pass to the peripheral blood.¹⁴ L-lactate is produced as the end product of the anaerobic glycolysis process. In sum, elevated lactate levels may predict early AII.¹⁵ Despite the promise, the diagnostic accuracy of serum lactate for diagnosing AII is heterogeneous with inconsistent results in the current evidence base. It remains inconclusive on whether serum lactate levels can accurately predict AII and the association between these levels and the extent of bowel necrosis. This has led to calls for evaluation of the diagnostic accuracy of D-lactate and L-lactate levels in predicting AII.¹⁶⁻¹⁸ Therefore, the present systematic review and diagnostic meta-analysis aimed to fill this knowledge gap by synthesizing current evidence on the diagnostic accuracy of lactate levels for early diagnosis of AII. Specifically, it aimed to separately meta-analyze studies reporting on D-Lactate, L-lactate, and serum plasma concentration. Such knowledge is essential to identify patients at the early stages of AII and intervene accordingly and promptly reducing morbidity and mortality.

METHODOLOGY

This review and meta-analysis followed the guidelines of the Cochrane Handbook Of Systematic Reviews of Diagnostic Test Accuracy¹⁹, and is reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines¹⁹, see Supplementary File 1. **It was registered in the** Prospective Register of Systematic Reviews database (PROSPERO) [CRD42024583735].

Search strategy and study selection

Ten electronic databases, registries, and grey literature repositories were extensively searched from inception up to 9th September 2024: PubMed, EMBASE, Scopus, SIGLE (System for Information on Grey Literature in Europe), NYAM (New York Academy of Medicine), Virtual Health Library, Controlled Trials (mRCT), ClinicalTrials.gov, WHO International Clinical Trials Registry Platform (ICTRP) and Google Scholar. Search strategy involved combination of the following two concepts (and related synonyms, keywords, and MeSH terms) using Boolean operators: 1) intestinal ischemia AND 2) lactate, see full strategy on Supplementary File 2. Additional studies were identified by hand searching reference lists on included studies. No language restrictions were set. All identified studies from searches were imported into Rayyan where title, abstract, and full text screening was done independently by two authors. Disagreements between the authors was resolved by discussion.

All studies with data relevant to the research question were included without restriction on patients' sociodemographic characteristics or study setting i.e. articles evaluating the diagnostic accuracy of serum lactate levels for early prediction of acute intestinal ischemia using relevant measures such as sensitivity, specificity, mean accuracy and/or mean area under the receiver operator curve (AUC). Acute mesenteric ischemia was defined based on intraoperative surgical diagnosis and pathological confirmation. Articles without empirical data such as reviews, non-diagnostic accuracy studies or with limited data such as conference abstracts were excluded.

Data extraction

A pre-prepared Microsoft Excel data extraction tool was used for the data extraction process. Data extracted included: 1) article characteristics (e.g. title, year of publication, authors); 2) sociodemographic and baseline clinical characteristics of participants (e.g., sex, age, body mass index, comorbidities ASA score, history of abdominal surgery, and history of intestinal obstruction); 3) Study methods (e.g. design, sample size and sampling methods, eligibility criteria, study outcomes, follow-up periods); 4) Outcome and complications data including acute intestinal ischemia causes, clinical presentations, level of obstruction, malignancy, laboratory markers, radiological findings, and surgical findings and outcomes; and 5) Predictor data including cut-

off values, median (interquartile range), and diagnostic accuracy measures of L-lactate, D-lactate, and plasma lactate including sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio, and AUC.

Risk of the bias and applicability concerns

The quality of the included diagnostic accuracy studies was assessed using the QUADAS-2 revised tool for the quality assessment of diagnostic accuracy studies²⁰.

Data analysis

Pooled sensitivity, specificity, positive likelihood ratio (PLR), negative likelihood ratio (NLR), diagnostic odds ratio (DOR), and their 95% confidence intervals (CI) were calculated and were displayed as forest plots. The summary receiver operating characteristic curve (SROC), area under the curve (AUC), and Q* index (point at which the sensitivity and specificity are equal) were calculated. AUC values of more than 80% represented the greatest potential for actual clinical application. Statistical heterogeneity was determined using Higgins *I*² statistic, at the value of > 50%, and the Cochrane Q (*Chi*² test), at the value of *p* < 0.10. Review Manager version 5.4 and MetaDisc software were used to analyze the data.^{21,22}

RESULTS

Figure 1 shows the PRISMA flow diagram. A total of 216 articles were identified with 155 of them being excluded as duplicates. After title, abstract and full text screening, 12 articles were included for data extraction and one study was identified throughout hand searching of reference lists making it 13 articles for the systematic review and meta-analysis.

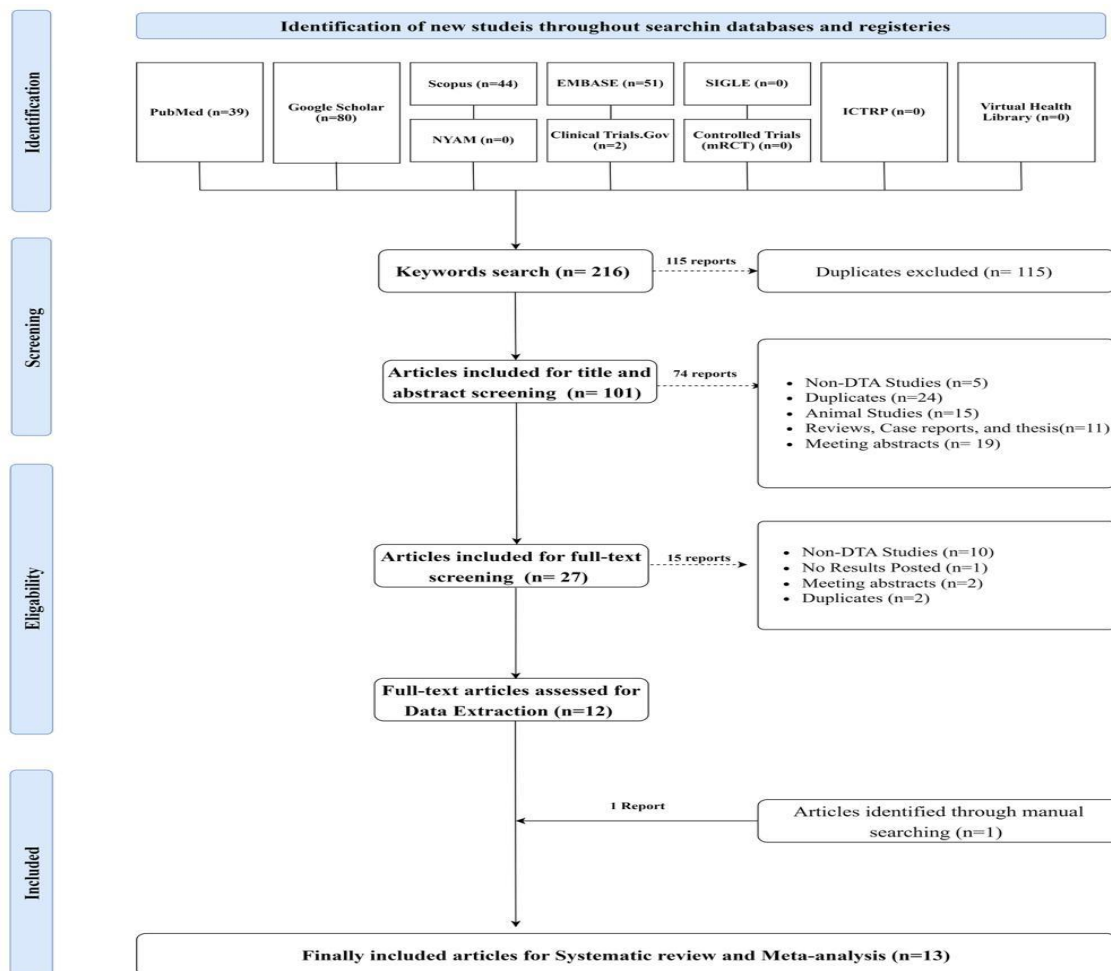


Figure 1. PRISMA Framework for the Study Criteria

Study design, participant demographic, and clinical characteristics

Table 1 shows the study design and participants’ demographic and clinical characteristics in the 13 included studies. The present diagnostic test accuracy meta-analysis included 13 articles, encompassing 1978 patients^{14, 23-34}, of whom, 600 had acute mesenteric ischemia. There were nine prospective cohort studies (of 13, 69.2%), three case-control studies (23.1%) and one cross-sectional study (7.7%). Five studies (38.5%) used plasma lactate concentration to evaluate acute intestinal ischemia, while four (30.8%) used D-lactate. The median level of serum lactate ranged from 1.49 to 2.79. There were 571 males and 335 females with an average age of 38-73 years. Ninety-one patients had a history of previous thromboembolic events, while 32 had a history of previous abdominal surgeries. Furthermore, 110 patients had vascular acute mesenteric ischemia, while 45 had non-vascular ischemia.

Table.1 Baseline demographic characteristics of the included studies

Author and year	Study country	Study design	Bio marker	Cut of f value	Media n level of seru m lactate	Sa mple size	Pro ven Int est ina l ische mi a	Pre val enc e	Gender		Age (Year s)	Comorbidit ies		Location of ischemia			Causes of ischemi a		
									Mal es	Fe males		Thro mboe mboli sm histor y	Pre vio us abd om ina l surger y	S mall bow el	S mall and lar ge bow el	La rge B ow el	Va scu lar	No n-Va scu lar	
				m m ol/ L		Num ber	Num ber	Per cen tag e	Num ber	Num ber	Media n (Rang e)/Me an±S D	Num ber	Num ber	Num ber	Num ber	Num ber	Num ber		
1	BA SO ĞL U et al., 1999[23]	Turkey	Cas e-cont rol stud y	D-lactate	0.0005	NR	22	12	54.5%	NR	NR	NR	NR	NR	8	4	NR	12	10
2	Bril lant ino et al., 2018[24]	Italy	Pros pect ive Coh ort stud y	L-lactate and D-lactate	2.05	1.5 (0.7-5.2)	284	83	29.2%	171	113	56±9.5	NR	NR	40	NR	8	48	35
3	Col lan ge et al., 2022[25]	France	Cas e-cont rol stud y	Ser um Lac tate	2	NR	274	137	50.0%	83	54	73 (62; 81)	NR	NR	NR	NR	NR	NR	NR
4	der Vo ort et al., 2014[34]	The Netherlands	Pros pect ive cohort	L-lactate	2.2	NR	120	23	19.2%	NR	NR	73 (64.0 :78.0)	NR	NR	NR	NR	NR	NR	NR
5	Des tek et al., 2020[26]	Turkey	Pros pect ive cohort	L-lactate	3	NR	51	25	49.0%	13	12	NR	7	5	NR	NR	NR	NR	NR
6	Kin tu-Lu wa	Uganda	Cros s-secti onal	Ser um Lac tate	2.2	1.72 (2.46)	70	40	57.1%	46	24	38 (52:25)	NR	NR	NR	NR	NR	NR	NR

	ga et al., 2013[27]					-1.26)													
7	Langet al., 1997[28]	Sweden	Prospective cohort	serum Lactate	24	NR	120	25	20.8%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
8	Lee et al., 2000[29]	Korea	Prospective cohort	L-lactate	NR	NR	100	17	17.0%	49	51	48.6±1.9	NR	NR	NR	NR	NR	NR	NR
9	Mothes et al., 2021[30]	Germany	Retrospective case-control	Serum Lactate	3	2.79 (1.8-4.8)	432	108	25.0%	79	29	70.7±9.9	NR	NR	NR	NR	NR	NR	NR
10	Nuzzo et al., 2021[32]	France	Prospective cohort	Serum D--lactate	0.012	1.49 (1.02 - 2.41)	129	50	38.8%	31	19	65 (55:75)	32	27	NR	NR	NR	50	0
11	Poeze et al., 1998[14]	The Netherlands	Prospective cohort	D-lactate	0.2	NR	24	11	45.8%	11	2	71.2±	NR	NR	NR	NR	NR	NR	NR
12	Shi et al., 2015[33]	China	Prospective cohort	D-lactate	0.1765	NR	272	39	14.3%	26	13	67.4 (8;87)	39	NR	NR	NR	NR	NR	NR
13	Novotny et al., 2022[31]	Czech Republic	Prospective cohort	L-lactate	NR	NR	80	30	37.5%	62	18	68.0 ± 8.4	13	NR	NR	NR	NR	NR	NR
Abbreviations; SD=Standard deviation, NR=Not reported																			

Risk of the bias and applicability of the included articles

Figure 2 shows the risk of bias and applicability of the included studies. Ten articles revealed a low risk of bias with patients' selection.^{14, 24, 26-29, 31-34} While Two articles revealed a low risk with the index test^{25, 31}, four articles had unclear risk with the reference standard test^{25, 26, 28, 29}. Ten articles revealed a low risk of flow and timing.^{14, 23, 24, 27, 29-34} All the included articles revealed a low risk of applicability concerns with patients' selection, whereas two articles showed unclear risk of applicability concerns with index test^{14, 31}. Ten articles showed a low risk of applicability concerns with reference standard test.^{25, 28, 29}

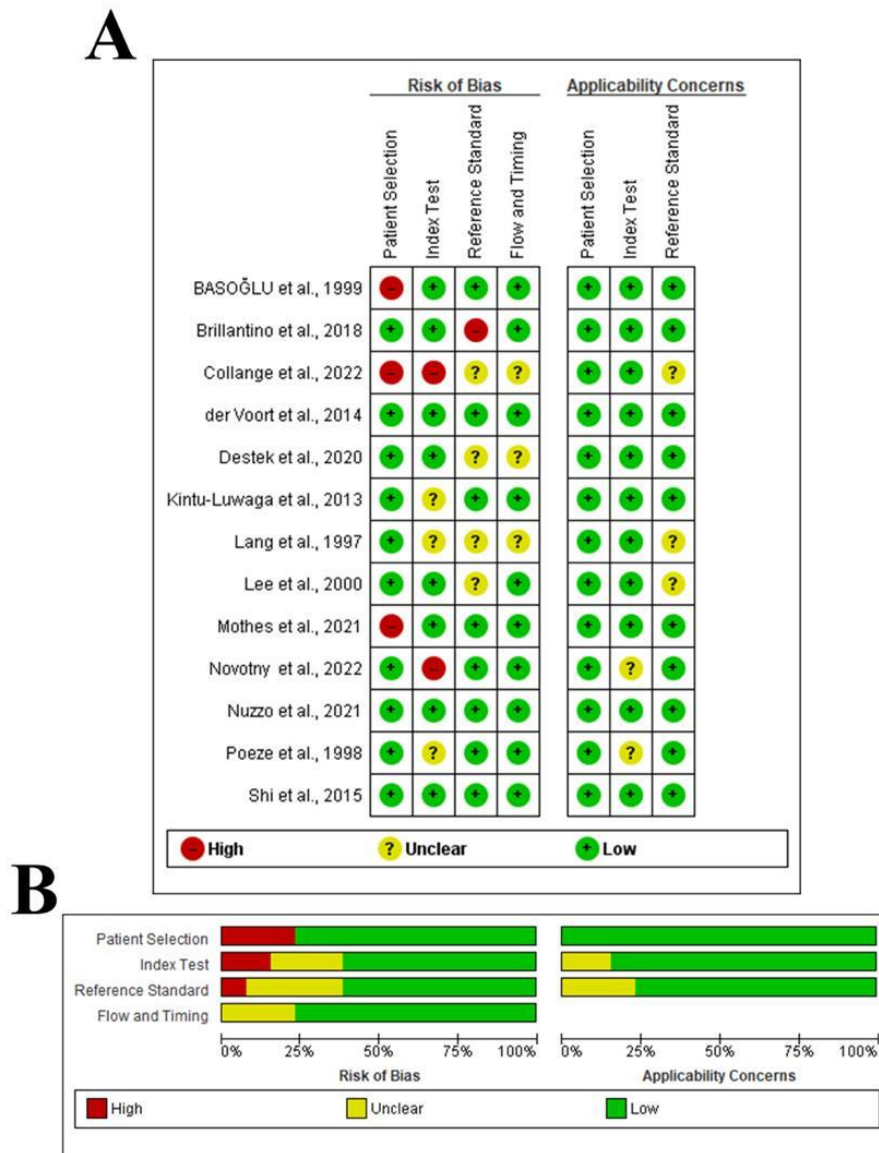


Figure 2. Risk of Bias and Applicability of the Included Studies

Diagnostic accuracy of serum lactate

Figure 2 shows the diagnostic accuracy characteristics of serum lactate. The pooled sensitivity of serum lactate was 0.84 (95%CI; 0.81, 0.87) with a statistical heterogeneity between the analyzed articles ($I^2=82.2\%$, $P<0.001$). The pooled specificity was 0.60 (95%CI; 0.57, 0.62) with a statistical heterogeneity between the analyzed articles ($I^2=96.5\%$, $P<0.001$). The pooled PLR and NLR were 2.28 (95%CI; 1.69, 3.07) and 0.24 (95%CI; 0.15, 0.40), respectively. The pooled AUC was 0.8361 with a standard error of 0.0510. (Figures. 2A, 2B, 2C, 2D, and 2E)

Diagnostic accuracy of D-Lactate, L-Lactate, and plasma lactate concentration

Figure 3 shows the diagnostic accuracy of D-Lactate, L-Lactate, and plasma lactate concentration. Four articles evaluated the diagnostic accuracy of D-lactate among patients with acute intestinal ischemia.^{14, 23, 31, 32} In the random-effects model, the pooled sensitivity was 0.94 (95%CI; 0.89, 0.98), and the pooled specificity was 0.54 (95%CI; 0.46, 0.61) with an AUC of 0.9015. The diagnostic accuracy of L-Lactate among patients with acute mesenteric ischemia was reported in four articles.^{26, 29, 33, 34} Pooling the data in the random-effects model revealed a pooled sensitivity of 0.81 (0.72, 0.87) and pooled specificity of 0.68 (95%CI; 0.64, 0.72) with an AUC of 0.8288. Five articles evaluated the diagnostic accuracy of plasma lactate concentration among patients with acute mesenteric ischemia.^{24, 25, 27, 28, 30} The pooled sensitivity and specificity were 0.82 (95%CI; 0.78, 0.86) and 0.56 (95%CI;

0.53, 0.60) with an AUC of 0.8196.

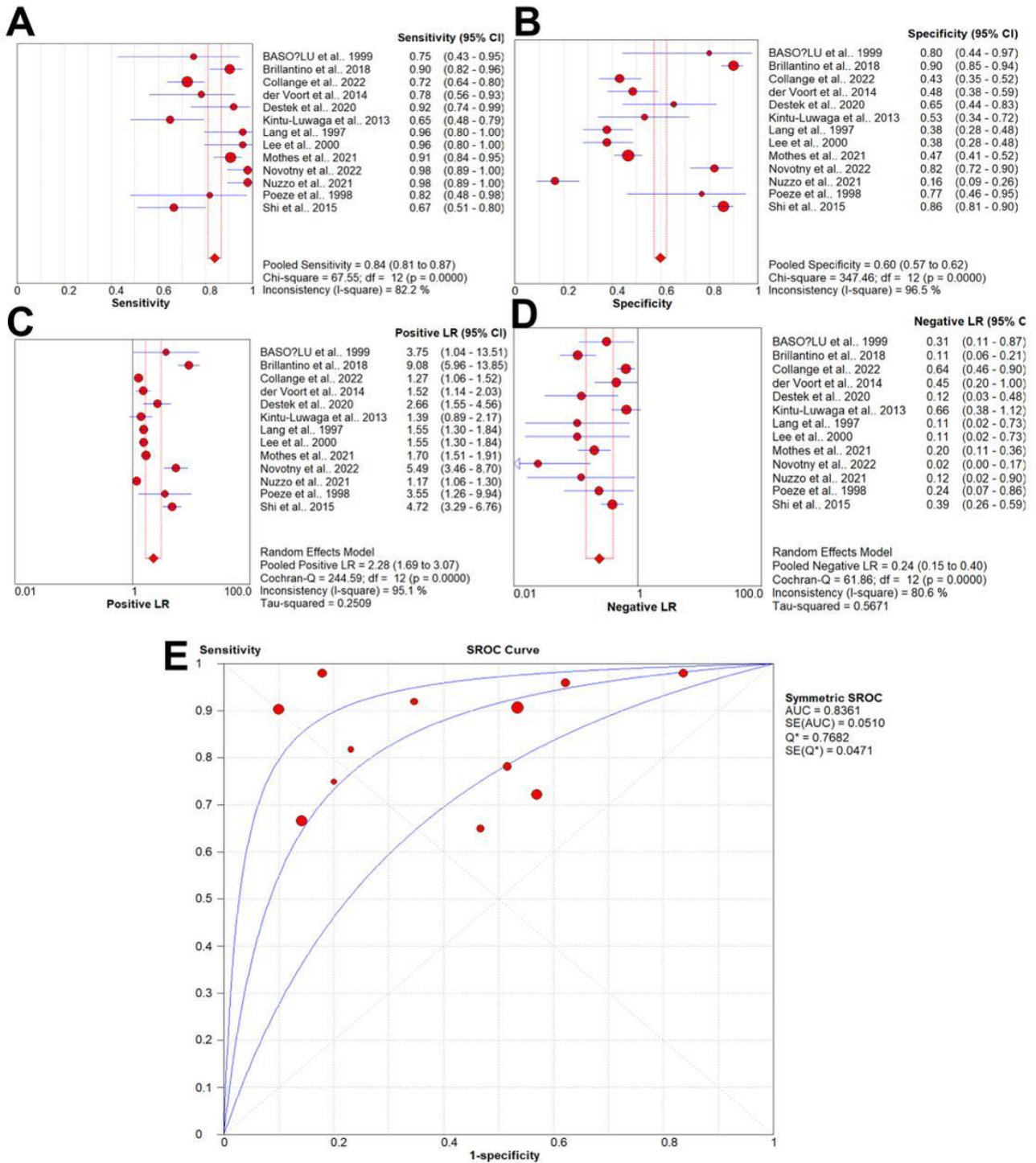


Figure 3. Diagnostic Accuracy of D-Lactate, L-Lactate, and Plasma Lactate Concentration

DISCUSSION

This systematic review and meta-analysis aimed to assess the diagnostic accuracy of serum lactate for AII, an often-challenging condition to diagnose due to its nonspecific clinical presentation. Our findings provide valuable insights into the potential utility and limitations of serum lactate, with implications for clinical practice and future research.^{35, 36} The present meta-analysis revealed the diagnostic accuracy of serum lactate to identify AII cases. This high sensitivity suggests that serum lactate could serve as an effective initial screening tool, especially for ruling out AII in high-risk populations. However, the specificity was relatively low, reflecting a significant proportion of false positives. This finding limits its reliability as a standalone diagnostic tool for confirming AII and underscores the need for complementary diagnostic methods, such as imaging or clinical scoring systems. Furthermore, serum lactate provides only a modest increase in the likelihood of AII when elevated. Conversely, the pooled NLR of 0.24 indicates that normal serum lactate levels effectively lower the probability of AII, making it more useful in

excluding rather than confirming the condition. The overall diagnostic performance, as measured by the AUC suggests that serum lactate has good discriminatory ability, though not exceptional enough for standalone clinical use. These findings are consistent with previous studies highlighting lactate as a sensitive but nonspecific biomarker in ischemic conditions.

Subgroup analyses of D-lactate, L-lactate, and plasma lactate concentrations revealed important variations in diagnostic performance. D-lactate emerged as the most promising marker, with a pooled sensitivity of 94% and an AUC of 0.9015. These findings support its superior diagnostic potential compared to other lactate subtypes. D-lactate's higher accuracy may be attributed to its direct relationship with intestinal ischemia, as it is produced by gut bacteria during hypoxia and ischemia, making it more specific to intestinal pathology. In contrast, L-lactate and plasma lactate showed more modest diagnostic performance, with sensitivities of 81% and 82%, respectively, and specificities of 68% and 56%. The relatively lower specificity of plasma lactate likely reflects its systemic production under various conditions, including sepsis, hypovolemia, and cardiogenic shock, which are common in critically ill patients. These findings suggest that D-lactate may be more suitable for clinical use in settings where AII is suspected, while L-lactate and plasma lactate could still provide value as part of a broader diagnostic approach.^{33, 37}

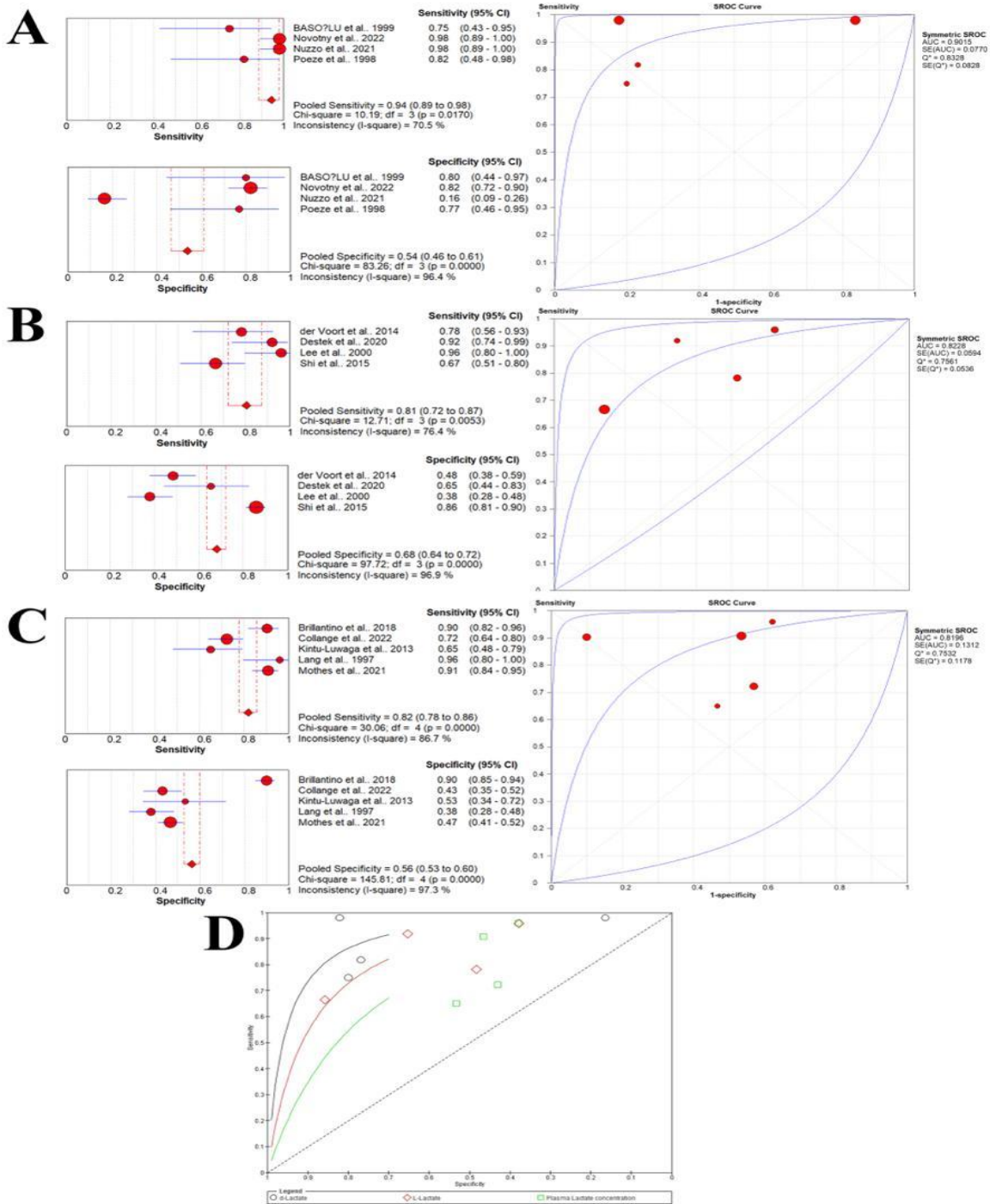


Figure 4. Sensitivity and Specificity of D-Lactate, L-Lactate, and Plasma Lactate Concentration

High statistical heterogeneity was observed, particularly in specificity estimates. This variability likely reflects differences in study design, patient populations, and methodologies. For instance, the inclusion of both vascular and non-vascular ischemia cases may have influenced diagnostic accuracy, as the pathophysiology and lactate production mechanisms differ between these subtypes. Additionally, variations in comorbidities, such as prior thromboembolic events or abdominal surgeries, may have impacted serum lactate levels across studies. Furthermore, differences in lactate assays, cutoff values, and time intervals between symptom onset and measurement contributed to the observed heterogeneity. These findings emphasize the importance of standardizing lactate measurement protocols in future research. About risk of bias and applicability, most included studies demonstrated a low risk of bias, particularly in in-patient selection and timing of the index test, which strengthens the reliability of the pooled estimates. However, several studies had an unclear risk of bias related to reference standards, potentially introducing variability in diagnostic accuracy. Despite these limitations, all studies were deemed to have low applicability concerns for patient selection, suggesting that the findings are broadly relevant to clinical practice.^{18, 38}

The results of this meta-analysis support the use of serum lactate as an adjunctive diagnostic tool for AII. Its high sensitivity makes it valuable for early detection, especially in resource-limited settings where advanced imaging may not be readily available. However, its limited specificity and substantial heterogeneity necessitate caution when interpreting elevated serum lactate levels. Clinicians should consider combining serum lactate measurements with other diagnostic modalities, such as imaging, clinical scoring systems, or other biomarkers like intestinal fatty acid-binding protein (I-FABP), to improve diagnostic accuracy. Among the lactate subtypes, D-lactate shows the greatest potential for clinical application, particularly in specialized settings where its measurement is feasible. However, the utility of L-lactate and plasma lactate in broader clinical settings cannot be dismissed, especially when access to D-lactate assays is limited.

A previous systematic review was published by Reintam Blaser A et al.¹⁸ and in comparing our findings with this review, both studies highlight the diagnostic potential of biomarkers for acute mesenteric ischemia (AMI), but with differences in focus and findings. Our meta-analysis found that serum lactate, especially D-lactate, showed high sensitivity (0.94) but lower specificity (0.54), suggesting its value for screening AMI, although it may not be as reliable for ruling it out. In contrast, the referenced review identified ischemia-modified albumin (IMA) and interleukin-6 (IL-6) as the most accurate biomarkers for AMI, with IMA showing the highest sensitivity and specificity (94.7% and 90.5%, respectively). Our study highlighted lactate as a promising marker, especially D-lactate, but with moderate specificity, which contrasts with the higher specificity found for IMA and IL-6. Additionally, while the referenced review explored multiple biomarkers, including I-FABP, our study focused on lactate subtypes, suggesting that a combination of markers, including lactate and others like IMA and IL-6, might offer more accurate diagnostic results for AMI. Another review was conducted by Evennett NJ et al.³⁸ and several similarities and differences are observed. Both studies report high sensitivity for D-lactate, suggesting its potential as a useful screening tool for AMI, although neither study found sufficient specificity to rely on it as a definitive diagnostic marker. Both studies also noted significant heterogeneity, particularly in specificity and positive likelihood ratios, highlighting variability across the studies included in each meta-analysis. However, there are some differences in the findings. Our study found higher sensitivity (0.94) compared to the other study (0.82), but with slightly lower specificity (0.54 vs. 0.48). In contrast, the comparison study reported a higher positive likelihood ratio (3.04 vs. 2.28), suggesting stronger diagnostic confirmation when D-lactate is positive in their study population. The negative likelihood ratios were similar between both studies (0.24 in our study vs. 0.35 in the other study), indicating that D-lactate's ability to rule out AMI is moderate in both. These differences and similarities emphasize that while D-lactate shows promise for screening AMI, its diagnostic performance is not optimal, and further research is needed to improve its accuracy, potentially by combining it with other biomarkers or diagnostic methods.

Study strengths and limitations

This meta-analysis provides the most up to date and comprehensive evidence on diagnosis accuracy of lactate levels for AII. It is based on a search of 10 databases and includes global literature without time restrictions. Several limitations in this meta-analysis need to be considered. First, the significant variation between studies affects the ability to apply the findings broadly. Second, the inclusion of both prospective cohort and case-control studies may have introduced selection bias, which could influence the results. Third, the limited number of studies that focused on specific types of serum lactate reduces the reliability of the subgroup analyses. Finally, differences in lactate measurement methods and cutoff values make it challenging to directly compare results across studies. To overcome these issues, future research should aim to standardize lactate measurement techniques and establish consistent diagnostic thresholds. Larger, multicenter, prospective studies are needed to further validate the accuracy of lactate subtypes, especially D-lactate, in diverse patient groups. Moreover, combining lactate with other biomarkers and imaging technologies could lead to a more effective, comprehensive diagnostic approach for AII.

CONCLUSION

Serum lactate, especially D-lactate, demonstrates promise as a diagnostic biomarker for AII, offering high sensitivity and moderate overall diagnostic performance. However, its limited specificity and substantial heterogeneity highlight the need for cautious use. Standardized protocols and the integration of serum lactate with other diagnostic modalities are crucial for optimizing its clinical utility and improving outcomes in patients with AII.

REFERENCES

1. Najah H, Trésallet C. Cirugía de las oclusiones agudas del intestino delgado en el adulto. *EMC-Técnicas Quirúrgicas-Aparato Digestivo*. 2019;35(4):1-22.
2. Rami Reddy SR, Cappell MS. A systematic review of the clinical presentation, diagnosis, and treatment of small bowel obstruction. *Current gastroenterol rep*. 2017;19:1-14.

3. Jackson P, Cruz MV. Intestinal obstruction: evaluation and management. *Am fam physician*. 2018;98(6):362-7.
4. Ten Broek RP, Krielen P, Di Saverio S, Coccolini F, Biffi WL, Ansaloni L, et al. Bologna guidelines for diagnosis and management of adhesive small bowel obstruction (ASBO): 2017 update of the evidence-based guidelines from the world society of emergency surgery ASBO working group. *World J of Emerg Surg*. 2018;13:1-13.
5. Scott JW, Olufajo OA, Brat GA, Rose JA, Zogg CK, Haider AH, et al. Use of national burden to define operative emergency general surgery. *JAMA Surg*. 2016;151(6):e160480-e.
6. Washington C, Carmichael JC. Management of ischemic colitis. *Clinics in colon and rectal surgery*. 2012;25(4):228-35. Epub 2013/12/03. doi: 10.1055/s-0032-1329534. PubMed PMID: 24294125; PubMed Central PMCID: PMC3577613.
7. Evennett NJ, Petrov MS, Mittal A, Windsor JA. Systematic review and pooled estimates for the diagnostic accuracy of serological markers for intestinal ischemia. *World J of Surg*. 2009;33:1374-83.
8. Sarr MG, Bulkley GB, Zuidema GD. Preoperative recognition of intestinal strangulation obstruction: prospective evaluation of diagnostic capability. *The Am J of Surg*. 1983;145(1):176-82.
9. Menke J. Diagnostic accuracy of multidetector CT in acute mesenteric ischemia: systematic review and meta-analysis. *Radiol*. 2010;256(1):93-101.
10. Bala M, Kashuk J, Moore EE, Kluger Y, Biffi W, Gomes CA, et al. Acute mesenteric ischemia: guidelines of the World Society of Emergency Surgery. *World J of Emerg Surg*. 2017;12:1-11.
11. Oldenburg WA, Lau LL, Rodenberg TJ, Edmonds HJ, Burger CD. Acute mesenteric ischemia: a clinical review. *Arch of internal med*. 2004;164(10):1054-62.
12. Leone M, Bechis C, Baumstarck K, Ouattara A, Collange O, Augustin P, et al. Outcome of acute mesenteric ischemia in the intensive care unit: a retrospective, multicenter study of 780 cases. *Intensive care med*. 2015;41:667-76.
13. Acosta S, Block T, Björnsson S, Resch T, Björck M, Nilsson T. Diagnostic pitfalls at admission in patients with acute superior mesenteric artery occlusion. *The J of emerg med*. 2012;42(6):635-41.
14. Poeze M, Froon A, Greve J, Ramsay G. D-lactate as an early marker of intestinal ischaemia after ruptured abdominal aortic aneurysm repair. *British J of Surg*. 1998;85(9):1221-4.
15. Demir IE, Ceyhan GO, Friess H. Beyond lactate: is there a role for serum lactate measurement in diagnosing acute mesenteric ischemia? *Digestive surgery*. 2012;29(3):226-35.
16. Montagnana M, Danese E, Lippi G. Biochemical markers of acute intestinal ischemia: possibilities and limitations. *Ann of translational med*. 2018;6(17).
17. Derikx JP, Schellekens DH, Acosta S. Serological markers for human intestinal ischemia: A systematic review. *Best practice & research Clin gastroenterol*. 2017;31(1):69-74.
18. Reintam Blaser A, Starkopf J, Björck M, Forbes A, Kase K, Kiisk E, et al. Diagnostic accuracy of biomarkers to detect acute mesenteric ischaemia in adult patients: a systematic review and meta-analysis. *World J of Emerg Surg*. 2023;18(1):44.
19. Deeks JJ, Bossuyt PM, Leeflang MM, Takwoingi Y. *Cochrane handbook for systematic reviews of diagnostic test accuracy*: John Wiley & Sons; 2023.
20. Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann of internal med*. 2011;155(8):529-36.
21. Collaboration C. Review Manager (RevMan), version 5.4. 2020. 2022.
22. Zamora J, Muriel A, Abrair V. MetaDiSc Version Beta (1.0. 10): Meta-analysis of diagnostic and screening tests. User manual. 2004.
23. BASOĞLU M, BALIK A, KIZILTUNÇ A, AKÇAY F, ATAMANALP SS. Serum D (-)-Lactate and Nitric Oxide (NO) Levels in Acute Intestinal Ischemia. *Turkish J of Med Sci*. 1999;29(1):37-40.
24. Brillantino A, Iacobellis F, Renzi A, Nasti R, Saldamarco L, Grillo M, et al. Diagnostic value of arterial blood gas lactate concentration in the different forms of mesenteric ischemia. *Eur Jof Trauma and Emerg Surg*. 2018;44:265-72.
25. Collange O, Lopez M, Lejay A, Pessaux P, Ouattara A, Dewitte A, et al. Serum lactate and acute mesenteric ischaemia: An observational, controlled multicentre study. *Anaesthesia Critical Care & Pain Med*. 2022;41(6):101141.
26. Destek S, Yabancı A, Abik YN, Gül VO, Değer KC. Predictive and prognostic value of L-lactate, D-dimer, leukocyte, C-reactive protein and neutrophil/lymphocyte ratio in patients with acute mesenteric ischemia. *Turkish J of Trauma & Emerg Surg/Ulusal Travma ve Acil Cerrahi Dergisi*. 2020;26(1).
27. Kintu-Luwaga R, Galukande M, Owori FN. Serum lactate and phosphate as biomarkers of intestinal ischemia in a Ugandan tertiary hospital: a cross-sectional study. *Int J of emerg med*. 2013;6:1-7.
28. Lange H, Toivola A. Warning signals in acute abdominal disorders. Lactate is the best marker of mesenteric ischemia. *Lakartidningen*. 1997;94(20):1893-6.
29. Lee MJ, Oh DR, Park KN, Kim SK, Yang JH, Park SH. Usefulness of Serum Lactate in the Early Diagnosis of Intestinal Ischemia. *J of the Korean Society of Emerg Med*. 2000;11(4):457-63.
30. Mothes H, Wickel J, Sponholz C, Lehmann T, Kaluza M, Zanol J, et al. Monitoring of the progression of the perioperative serum lactate concentration improves the accuracy of the prediction of acute mesenteric ischemia development after cardiovascular surgery. *J of Cardiothoracic and Vascular Anesthesia*. 2021;35(6):1792-9.
31. Novotny T, Staffa R, Tomandl J, Krivka T, Slaby O, Kubicek L, et al. L-lactate kinetics after abdominal aortic surgery and intestinal ischemia—An observational cohort study. *Int J of Surg*. 2022;98:106220.
32. Nuzzo A, Guedj K, Curac S, Hercend C, Bendavid C, Gault N, et al. Accuracy of citrulline, I-FABP and D-lactate in the diagnosis of acute mesenteric ischemia. *Sci Rep*. 2021;11(1):18929.
33. Shi H, Wu B, Wan J, Liu W, Su B. The role of serum intestinal fatty acid binding protein levels and D-lactate levels in the diagnosis of acute intestinal ischemia. *Clin and res in hepatol and gastroenterol*. 2015;39(3):373-8.

34. van der Voort PH, Westra B, Wester JP, Bosman RJ, van Stijn I, Haagen I-A, et al. Can serum L-lactate, D-lactate, creatine kinase and I-FABP be used as diagnostic markers in critically ill patients suspected for bowel ischemia. *BMC anesthesiol.* 2014;14:1-10.
35. Bou Chebl R, El Khuri C, Shami A, Rajha E, Faris N, Bachir R, et al. Serum lactate is an independent predictor of hospital mortality in critically ill patients in the emergency department: a retrospective study. *Scandinavian J of trauma, resuscitation and emerg med.* 2017;25(1):69.
36. Baxter J, Cranfield KR, Clark G, Harris T, Bloom B, Gray AJ. Do lactate levels in the emergency department predict outcome in adult trauma patients? A systematic review. *J of Trauma and Acute Care Surg.* 2016;81(3):555-66.
37. van der Voort PH, Westra B, Wester JP, Bosman RJ, van Stijn I, Haagen I-A, et al. Can serum L-lactate, D-lactate, creatine kinase and I-FABP be used as diagnostic markers in critically ill patients suspected for bowel ischemia. *BMC anesthesiol.* 2014;14(1):111.
38. Evennett NJ, Petrov MS, Mittal A, Windsor JA. Systematic review and pooled estimates for the diagnostic accuracy of serological markers for intestinal ischemia. *World J of Surg.* 2009;33(7):1374-83.