Prognostic value of elevated lactate dehydrogenase in patients with COVID-19: a systematic review and meta-analysis

Januar Wibawa Martha, Arief Wirbowo, Raymond Pranata

ABSTRACT

Purpose This meta-analysis aimed to evaluate the prognostic performance of elevated lactate dehydrogenase (LDH) in patients with COVID-19.

Methods A systematic literature search was performed using PubMed, Embase and EuropePMC on 19 November 2020. The outcome of interest was composite poor outcome, defined as a combined endpoint of mortality, severity, need for invasive mechanical ventilation and need for intensive care unit care. Severity followed the included studies’ criteria.

Results There are 10 399 patients from 21 studies. Elevated LDH was present in 44% (34%–53%) of the patients. Meta-regression analysis showed that diabetes was correlated with elevated LDH (OR 1.01 (95% CI 1.00 to 1.02), p=0.038), but not age (p=0.710), male (p=0.068) and hypertension (p=0.969). Meta-analysis showed that elevated LDH was associated with composite poor outcome (OR 5.33 (95% CI 3.90 to 7.31), p<0.001; 1: 77.5%). Subgroup analysis showed that elevated LDH increased mortality (OR 4.22 (95% CI 2.49 to 7.14), p<0.001; 1: 89%). Elevated LDH has a specificity of 0.74 (95% CI 0.60 to 0.85), specificity of 0.69 (95% CI 0.58 to 0.78), positive likelihood ratio of 2.4 (95% CI 1.9 to 2.9), negative likelihood ratio of 0.38 (95% CI 0.26 to 0.55), diagnostic OR of 6 (95% CI 4 to 9) and area under curve of 0.77 (95% CI 0.73 to 0.80). Elevated LDH would indicate a 44% posterior probability and non-elevated LDH would indicate 11% posterior probability for poor prognosis. Meta-regression analysis showed that age, male, hypertension and diabetes did not contribute to the heterogeneity of the analyses.

Conclusion LDH was associated with poor prognosis in patients with COVID-19.

ELIGIBILITY CRITERIA

The inclusion criteria were letters and research articles reporting COVID-19 patients with information on LDH (dichotomous) along with mortality/severity/invasive mechanical ventilation (IMV)/critical care/intensive care unit (ICU) care. The exclusion criteria were preprint studies, conferences abstract, commentaries, letters containing no primary data, case reports and articles in a language other than English.

DATA EXTRACTION

Extraction of data from the included studies was performed by two individuals independently using extraction forms that consisted of author, year, study design, age, gender, diabetes, hypertension, cardiovascular diseases, LDH cut-off points and outcome of interests.

The key exposure was elevated LDH, defined as level of LDH above specific cut-off points defined by each individual study. The outcome of interest...
was composite poor outcome, defined as a combined endpoint of mortality, severity, need for IMV, and need for ICU care. Severity followed the included studies’ criteria. The effect estimate was reported as OR. Sensitivity and specificity, positive and negative likelihood ratio (PLR and NLR), diagnostic OR (DOR) and area under curve (AUC) were generated for the diagnostic meta-analysis.

**RISK OF BIAS ASSESSMENT**

Newcastle-Ottawa Scale was used to facilitate the quality assessment of the included studies. The assessment was performed by two individuals independently, and arising discrepancies were resolved by discussion.

**STATISTICAL ANALYSIS**

STATA V.16 (StataCorp) was used to perform statistical analysis. Meta-analysis of proportion was used to the incidence of poor composite outcome and elevated LDH. DerSimonian and Laird method random-effects model was used to calculate ORs. A p<0.05 was considered as statistically significant. Inter-study heterogeneity was assessed using the I² and Cochran Q test; a value of <50% or p<0.10 indicates significant heterogeneity. Restricted-maximum likelihood random effects meta-regression analysis was performed with age, gender, diabetes mellitus and hypertension as covariates, for the prevalence of elevated LDH and the association between elevated LDH and composite poor outcome. Funnel plot and Egger’s test were performed to assess publication bias. Trim-and-fill analysis was performed to account for the asymmetrical funnel plot. Pooled sensitivity and specificity, summary receiver operating characteristic curve, Fagan’s nomogram and Deek’s asymmetry test were performed. Univariate meta-regression and subgroup analyses were performed for age, male, hypertension and diabetes.

**RESULTS**

**Study selection and baseline characteristics**

There are 10 399 patients from 21 studies included in the qualitative and quantitative synthesis (figure 1). Baseline characteristics and risk of bias assessment of the included studies are displayed in table 1. The incidence of composite poor outcome was 25%.

**LDH and Poor Prognosis**

Elevated LDH was present in 44% (34%–53%) of the patients. Meta-regression analysis showed that diabetes was correlated with elevated LDH (OR 1.01 (95% CI 1.00 to 1.02), p=0.038), but not age (p=0.710), male (p=0.068) and hypertension (p=0.969). Meta-analysis showed that elevated LDH was
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LDH and Poor Prognosis

<table>
<thead>
<tr>
<th>Study ID</th>
<th>OR (95% CI)</th>
<th>% Weight</th>
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</thead>
<tbody>
<tr>
<td>Chen G 2020</td>
<td>9.00 (4.88, 16.59)</td>
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<td>Chen Z 2020</td>
<td>6.24 (2.77, 14.11)</td>
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<tr>
<td>Coenen M 2020</td>
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<td>Deng M 2020</td>
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<tr>
<td>Guo W 2020</td>
<td>3.73 (1.80, 7.71)</td>
<td>6.46</td>
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<td>Hong KS 2020</td>
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<td>Huang C 2020</td>
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<td>Huang Y 2020</td>
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<td>Jang 2020</td>
<td>19.95 (4.38, 89.86)</td>
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<td>Khamis F 2020</td>
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<td>Li X 2020</td>
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<td>7.09</td>
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<td>Mihani T 2020</td>
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<tr>
<td>Ramos-Rincon 2020</td>
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<tr>
<td>Wang F 2020</td>
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<tr>
<td>Wei Y 2020</td>
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<tr>
<td>Zhang J 2020</td>
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<td>Zheng 2020</td>
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<tr>
<td>Zhou F 2020</td>
<td>45.43 (6.10, 338.44)</td>
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<td>Overall (n=74)</td>
<td>5.33 (3.89, 7.30)</td>
<td>100.00</td>
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</table>

NOTE: Weights are from random effects analysis.

Figure 2 Forest-plot for lactate dehydrogenase and composit poor outcome. LDH, lactate dehydrogenase.

Diagnostic meta-analysis

Elevated LDH has a sensitivity of 0.74 (95% CI 0.60 to 0.85), specificity of 0.69 (95% CI 0.58 to 0.78) (figure 3), PLR of 2.4 (95% CI 1.9 to 2.9), NLR of 0.38 (95% CI 0.26 to 0.55), DOR of 6 (95% CI 4 to 9) and AUC of 0.77 (95% CI 0.73 to 0.80) (figure 4). Elevated LDH would indicate a 44% posterior probability and non-elevated LDH would indicate 11% posterior probability for poor prognosis (figure 5). Deek's asymmetry test was significant (p=0.004). Meta-regression analysis showed that age, male, hypertension and diabetes did not contribute to the heterogeneity of the analysis. Figure 6 shows the univariate meta-regression and subgroup analyses.

DISCUSSION

Elevated LDH was associated with poor prognosis in patients with COVID-19, indicating 37% posterior probability for ‘composite poor outcome’ with AUC of 0.77, sensitivity of 74%, and specificity of 69%.

The incidence of LDH was associated with presence of diabetes, this phenomenon might be due to reduced glycogen synthesis, change in glucose oxidative metabolism and elevated whole-body rate of non-oxidative glycolysis. These mechanisms cause elevated lactate in patients with insulin resistance compared with those without. LDH has been found to affect the prognosis of various diseases, including cancers.26 LDH elevation in patients with COVID-19 indicates lung and tissue injuries.27 COVID-19 may lead to inadequate tissue perfusion and multiple organ failure due to various mechanisms, including thrombosis, which lead to LDH elevation.28 Thus, high LDH serves as a biomarker of the disease extent. This study indicated that the association between LDH elevation and poor prognosis was not affected by age, gender, hypertension or diabetes; these factors were known to increase COVID-19 severity and its associated mortality, thus, may confound the association.29-33

Three studies reported that elevated LDH was independently associated with composite poor outcome (OR 5.33 (95% CI 3.90 to 7.31), p<0.001; F: 77.5%, p<0.001) (figure 2). Based on meta-regression, the effect estimate was found to not significantly vary with age (p=0.223), male (p=0.117), hypertension (0.445) and diabetes (p=0.583). The funnel-plot analysis showed an asymmetrical shape and Egger’s test demonstrates small-study effects (p=0.005). Trim-and-fill analysis was performed, and the addition of 6 imputed studies on the left side, the OR became 4.31 (95% CI 3.00 to 6.20]. Subgroup analysis showed that elevated LDH increased mortality (OR 4.22 (95% CI 2.49 to 7.14), p<0.001; F: 89%, p<0.001).

Figure 3 Pooled sensitivity and specificity. LDH, lactate dehydrogenase.
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associated with poor prognosis (HR 1.01, HR 2.00 and OR 1.63).15 19 21 One study reported that elevated LDH was lost its statistical significance after adjustment.20

The heterogeneity might be due to different cut-off points, lab references and diagnostic tools. Another possible explanation was due to the very different methods by which patients with COVID-19 get the attention of medical services. Nevertheless, most of the studies demonstrate that elevation of LDH for at least >250 U/L was associated with poor prognosis. Funnel-plot analysis and Egger’s test indicate small study effect in the pooled estimate. Trim-and-fill analysis was performed to evaluate whether the adjustment to publication bias will cause the effects estimate to become non-significant. With the imputation of six hypothetical studies the OR was only reduced slightly (OR 4.31 vs 4.22), indicating the robustness of the effect estimate. Thus additional studies are unlikely to nullify the prognostic performance of this meta-analysis.

The pooled result is that LDH has poor predictive performance; and might be similar to other metabolic marker of physiological distress (Troponin, C reactive proteins, white cell count, d-dimer, brain natriuretic peptide (BNP) and others),38 39 thus, it should be studies further and integrated into a risk prediction model rather used alone. This result adds to the literature that elevated LDH is associated with poor outcome, whether they are discriminatory requires further investigation with large sample size.

This systematic review’s limitation was mainly due to retrospective studies, which have a higher potential for bias. Additionally, different cut-off points may cause high heterogeneity. Future studies are suggested to use single cut-off points for prognostic purposes. Drugs associated with comorbidities, such as metformin and renin–angiotensin–aldosterone system.

Figure 4 Summary receiver operating characteristics (SROC) curve.

Figure 5 Fagan’s normogram. LR, likelihood ratio.

Figure 6 Univariable meta-regression and subgroup analyses.

inhibitor, may affect LDH, the studies inadequately report these.

CONCLUSION
LDH was associated with poor prognosis in patients with COVID-19.

Main messages
⇒ Elevated lactate dehydrogenase (LDH) has a sensitivity of 74% and specificity of 69%.
⇒ Elevated LDH would indicate a 44% posterior probability and non-elevated LDH would in indicate 11% posterior probability for poor prognosis.
⇒ Meta-regression analysis showed that age, male, hypertension and diabetes did not contribute to the heterogeneity.

Current research question
⇒ Future studies are suggested to use a single cut-off point for prognostic purposes.
⇒ Integrating lactate dehydrogenase into a model may enhance prognostication.
⇒ More prospective studies are required for a higher quality of evidence.

What is already known on the subject
⇒ Lactate dehydrogenase (LDH) catalyses the last step of aerobic glycolysis, the pyruvate to lactate conversion.
⇒ Elevated LDH signifies tissue hyperperfusion indicates the extent of the disease, hence, may affect prognosis in COVID-19.
⇒ There are studies showing that elevated LDH was associated with mortality, and some studies did not.

Correction notice This article has been corrected since it first published. The provenance and peer review statement has been included.

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ORCID iDs
Januar Wilbawa Martha http://orcid.org/0000-0001-8993-3197
Arief Wibowo http://orcid.org/0000-0001-9217-2202
Raymond Panrata http://orcid.org/0000-0003-3998-6551

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