Liver injury in COVID-19: Known and unknown

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Abstract

Since the first report of the coronavirus disease 2019 (COVID-19) in December 2019 in Wuhan, China, the outbreak of the disease is currently continuously evolving. Previous studies have shown varying degrees of liver damage in patients with COVID-19. However, the exact causes of liver injury and the relationship between COVID-19 and liver injury is unclear. This article describes liver injury induced by COVID-19, analyzes its causes, and discusses the treatment and prognosis of liver damage in patients with COVID-19.

Key Words: SARS-CoV-2; COVID-19; Liver injury; Prognosis; Treatment

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Core Tip: This review describes the causes of liver injury in patients with coronavirus disease 2019 (COVID-19), including inflammatory storms, hypoxia, drug factors, and viral damage to liver cells, and discusses the treatment of liver injury with COVID-19, which we believe to be beneficial to manage COVID-19 patients with liver injury well and improve their prognosis.

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INTRODUCTION
Since the pandemic of coronavirus disease 2019 (COVID-19) in November 2019 in Wuhan, more than 70 million people have been diagnosed with COVID-19 and over 1.6 million have died. According to the report of the World Health Organization, people with COVID-19 have spread to 220 countries and regions on December 17, 2020. How to control the spread of COVID-19 has become the most urgent problem that we are facing. Some vaccines have been launched in many countries. But we still need to take effective measures to cure the infected and reduce the mortality.

Besides the lung, the liver is one of the main target organs of COVID-19[1]. Previous studies found that the incidence of liver injury in patients with severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) infection is 14%-53% [2-6] and that liver injury increases the ventilator risk and mortality of patients with COVID-19. The relationship between COVID-19 and liver injury is unclear. Thus, this article reviews the relationship between these concepts.

LIVER INJURY INDUCED BY COVID-19
Liver injury caused by SARS-CoV-2 can be classified into hepatocyte type, cholangiocyte type, and mixed liver injury[7,8]. Transaminases, bilirubin (Bili), alkaline phosphatase, lactate dehydrogenase (LDH), and albumin (Alb) can be used as the biochemical indicators of liver injury[9-11]. Liver injury was defined as increased levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in Fan et al’s research[12]. However, liver injury was identified when the levels of ALT and AST are three-fold higher than normal and Bili two-fold higher[13], which is one possible reason of different incidence rates of liver injury in COVID-19 patients. Only three (3.75%) patients showed liver dysfunction of the 80 patients with COVID-19 since most of the cases in this study were mild and moderate, with a median age of 46.1 years[14]. Wang et al[15]’s meta-analysis showed that 2.6%-53% of patients had abnormal levels of ALT, AST, and total bilirubin (TB), and 6%-98% had abnormal levels of Alb in COVID-19. Transient increases in AST and ALT are commonly seen in mild and moderate COVID-19 patients[16]. Peak aminotransferases were about six to nine-fold higher, while peak total bilirubin was about two-fold higher in severe COVID-19 patients. Peak ALT correlated with peak AST levels[17]. While the values of ALT, AST, and Bili in severe COVID-19 patients are higher than those in non-severe patients, the value of Alb was significantly lower in severe cases[9]. Severe patients also displayed a markedly prolonged activated partial thromboplastin time (APTT), which reflected coagulopathy[17,18].

Critically ill patients were more likely to be older male individuals with a higher prevalence of coronary heart disease, diabetes mellitus, hypertension, malignancy, and chronic obstructive pulmonary disease, compared to non-critically ill patients[10]. Inactive HBV carriers with mild SARS-CoV-2 co-infection are at a higher risk of enhanced liver injury, which was identified as the hepatocyte type rather than the cholangiocyte type[19]. Complications including acute-on-chronic liver failure (ACLF), acute cardiac injury, and shock happened more frequently in patients with severe COVID-19 and chronic HBV co-infection, and the mortality rate was higher in individuals with liver injury[20]. In 202 patients with confirmed COVID-19 and information relating to non-alcoholic fatty liver disease (NAFLD), the elevated ALT level was observed in 101 (50%) and 152 (75.2%) patients on admission and during hospitalization, respectively, which was significantly higher than that of patients without NAFLD[21]. In COVID-19 patients with chronic liver disease, 43% of non-cirrhotic patients presented with acute liver injury and 20% cirrhosis presented with either acute-on-chronic liver failure or acute liver decompensation[22]. Mortality was significantly higher in patients with cirrhosis and COVID-19 than in those with bacterial infections[23] (Table 1).

LIVER DAMAGE IN ASYMPTOMATIC COVID-19 PATIENTS
Asymptomatic COVID-19 patients do not present specific symptoms and signs. As such, they are often diagnosed via nucleic acid monitoring. Currently, asymptomatic infected patients account for 17.9%-30.8% of all COVID-19 cases[24,25]. However, asymptomatic and symptomatic patients with COVID-19 have the same virus load[26] and thus likely play major roles in virus transmission[27,28]. To prevent virus trans-
mission, scientists have been studying the characteristics of patients with asymptomatic SARS-CoV-2 infection, but they have yet to perform large clinical studies on the characteristics of the liver function of asymptomatic COVID-19 patients.

Uhm et al. [29] compared the liver function of asymptomatic and non-severe patients with COVID-19; they found that their ALT and AST levels are within the normal range and have no significant differences between the two groups. This finding may be related to the severity of the selected patients. Another study has conducted liver function tests on nine patients among 34 asymptomatic COVID-19 patients at early stages and showed that the ALT, AST, and Alb are all within their normal ranges [30]. Similarly, the liver function tests of 50 asymptomatic patients among 648 patients with COVID-19 from 25 hospitals in Jiangsu Province have shown that the Alb, AST, and ALT levels of symptomatic patients are within their normal ranges [31]. Han et al. [32] analyzed the ALT, AST, ALP, TP, ALB, and total bilirubin (TBL) levels of 25 asymptomatic COVID-19 patients. They observed that the AST and ALT levels of symptomatic patients are significantly higher than those of asymptomatic patients. Conversely, the albumin and total protein levels of asymptomatic patients are lower than those of symptomatic patients. The bilirubin levels of the two groups are not significantly different. Another study has monitored the liver function of 15 patients among 342 symptomatic COVID-19 patients before and during hospitalization. Its results have revealed the following: Increased ALT levels in three patients, increased LDH levels in six, and decreased ALB levels in two. During treatment, the following findings have been noted: Increased ALT levels in four patients, with the highest value of 106 U/L; decreased albumin levels in three patients, with the lowest value of 31.6 g/L; and increased LDH levels in six patients, with the highest value of 504 U/L. This result has also indicated that the liver function of asymptomatic patients may be damaged [33]. However, further studies should be conducted to analyze the character-

### Table 1 Overview of included papers regarding coronavirus disease 2019

| Ref. | Country | City | Sample size (n) | Male, n (%) | History of liver disease (%) | Abnormal liver bio-chemical indicators at admission or during hospitalization, n (%) |
|------|---------|------|----------------|-------------|-----------------------------|---------------------------------------------------------------------------------|
| Chu et al. [7] | China | Wuhan | 838 | 464 (55.3) | NA | Elevated ALT 429 (51.1); Elevated AST 429 (51.1); Elevated TBL 429 (51.1) |
| Piano et al. [8] | Italy | NA | 565 | 357 (63.1) | 31 (6) | Elevated ALT 329 (58); Elevated AST 329 (58); Elevated TBL 329 (58) |
| Huang et al. [10] | China | Jiangsu | 2623 | 1312 (50) | NA | Decreased albumin levels: 1230 (46.9) on the first laboratory test; 1435 (54.7) on the second test after hospitalization |
| Huang et al. [11] | China | Shenzhen | 417 | 198 (47.5) | 21 (5.04) | 318 (76.3) had abnormal liver test results; 90 (21.5) had liver injury during hospitalization. |
| Fan et al. [12] | China | Shanghai | 148 | 75 (50.7) | NA | 55 (37.2) with abnormal liver function tests on admission; 45 (48.4) developed liver functional abnormality 7 d after admission |
| Wu et al. [14] | China | Yancheng/Wuxi | 80 | 39 (48.7) | NA | Abnormal ALT 3 (3.75); Abnormal AST 3 (3.75); Abnormal Alb 2 (2.50) |
| Da et al. [16] | United States | New York | 5 | 3 (60) | NA | Abnormal ALT 5 (3.75); Abnormal AST 5 (3.75); Abnormal Alb 4 (2.50) |
| Da et al. [17] | United States | New York | 176 | 103 (58.5) | NA | Abnormal ALT 109 (61.9); Abnormal AST 109 (61.0) |
| Fu et al. [18] | China | Wuhan | 355 | 190 (53.5) | 16 (4.5) | 151 (42.5) with cholestasis; 101 (28.5) with hepato-cellular injury |
| Lin et al. [19] | China | Chongqing | 133 | 72 (54.1) | 17 (12.7) | Elevated ALT 31 (23.3); Elevated AST 27 (20.3) |
| Zou et al. [20] | China | Wuhan | 105 | 55 (52.3) | 105 (100) | Elevated ALT 22 (20.95); Elevated AST 29 (27.62) |
| Ji et al. [21] | China | NA | 202 | 113 (55.9) | NA | Elevated ALT 101 (50.0); Elevated AST 34 (16.8); Elevated TBL 17 (8.4) |
| Sarin et al. [22] | NA | NA | 228 | 132 (57.8) | 132 (100) | NA |
| Iavarone et al. [23] | Italy | Lombardy | 50 | 35 (70) | 50 (100) | Elevated ALT 29 (58); Elevated AST 32 (67) |

NA: Not available; ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; TBIL: Total bilirubin.
The causes of liver damage are multifold. The inflammatory reaction damages the liver. COVID-19 leads to local inflammation in the affected area of the lung and induces the production of pro-inflammatory cytokines and chemokines, such as IL-6, IFN-γ, M-CSF, and MCP1. IL-6 induces acute inflammation by recruiting neutrophils, which can cause liver injury and increase transaminase levels. The inflammatory storm induced by severe COVID-19 causes the release of a large number of inflammatory mediators into the blood circulation, thereby damaging the liver function. Disease-related inflammatory reactions and disease exacerbation may explain the death of some critical patients. The markers ferritin, IL-8, IL-6, and TNF-α significantly increase in the acute inflammatory phase. IL-6 is positively correlated with increased AST, TBIL, and ALP. IL-8 is positively correlated with increased AST, and TNF-α is positively correlated with increased ALT, AST, and GGT. Although IL-6 is significantly increased in patients with liver injury, no causal relationship between this cytokine and liver injury has yet been confirmed. Other scholars have reported that IL-8, TNF-α, and IL-1β may not have a significant relationship with liver injury. Severe patients are more prone to liver damage and show significantly increased levels of inflammatory cytokines compared with mild patients. IL-2 and IL-17A have been suggested to be key inflammatory factors causing liver injury in COVID-19 patients. The early increase in AST level and its correlation with disease severity indicate that immune-mediated inflammation plays an important role in liver injury in severe COVID-19 patients.

Hepatotoxic drugs damage the liver function. COVID-19 patients are often prescribed with antiviral drugs, antibiotics, antifungal drugs, and systemic glucocorticoid drugs. These drugs could result in the elevation of liver transaminase levels. Some antiviral drugs may have potential hepatotoxicity. For example, lopinavir/ritonavir is mainly affected by cytochrome p450 3A4 in the liver. Patients treated with lopinavir/ritonavir combined with arbidol often show liver damage, and the incidence of liver injury in this group may be up to 3.58 times greater than that in patients who did not receive the same treatment. Drug treatment increases the likelihood of liver damage by 12.1%. Some patients may be given symptomatic treatment with acetaminophen and other drugs during hospitalization. Large doses or combinations of these drugs with other medications can cause liver toxicity and even liver failure. In a study of seven COVID-19 patients who were administered with tocilizumab treatment, the drug increased transaminase levels in all patients by up to fivefold compared with normal levels, but the CRP levels and liver function returned to normal within 3 wk. However, Campochiaro et al. reported that tocilizumab treatment does not significantly reduce mortality in patients with COVID-19. These contradictory findings suggest that great care should be taken when providing tocilizumab treatment. Patients treated with remdesivir also showed liver transaminase elevation, which indicates that the antiviral drug may cause liver cell injury.

Hypoxia may be another cause of liver injury. The release of a large number of inflammatory cytokines induces acute respiratory distress syndrome (ARDS) and systemic inflammatory response syndrome (SIRS) and causes hypoxia, which leads to lung, liver, myocardial, and kidney damage. Microthrombi and hemophagocytes have been noted in the liver biopsy of patients with COVID-19, suggesting that ischemia may be a potential cause of liver injury. Liver biopsy of COVID-19 patients revealed moderate microvascular steatosis and mild liver lobule and portal lesions. Hypoxia caused by COVID-19-related complications, such as respiratory distress syndrome or multiple organ failure, can also cause liver ischemia and hypoxia-reperfusion dysfunction, which is more severe in serious cases than in mild COVID-19 patients.

Studies have found that ACE2 is the key receptor through which SARS-CoV-2 cells are able to enter cells. The expression of ACE2 in liver cells is very low and occurs mainly in bile duct cells; this finding indicates that hepatic bile duct cells may be the site of direct assault of the novel virus. Eleven patients were found to be PCR positive in 20 deceased COVID-19 patients; moreover, although the results were not statistically significant, the AST peak of PCR-positive patients was higher than that of PCR-negative patients. The liver pathology of one deceased patient showed no bile duct.
injury or virus infiltration, and LDH and GGT, which reflect bile duct damage, were not significantly increased[36].

**IMPACT OF LIVER INJURY ON PATIENT PROGNOSIS**

Abnormal liver function indices can be used to judge the severity of COVID-19. Compared with other indicators of liver injury, COVID-19 patients with abnormal AST have a greater mortality[33]. A high ratio of white blood cells to lymphocytes indicates that the systemic inflammatory response is activated. Liver steatosis and the ratio of neutrophils to lymphocytes are related to disease severity[54]. The ratio of white blood cells to lymphocytes is an independent risk factor influencing the mortality of patients with COVID-19 and liver injury. Patients with chronic liver disease generally experience longer hospital stays than those without. Unfortunately, prolonged hospital stays increase the risk of nosocomial infection, which contributes to a poor patient prognosis[55]. Some studies revealed no obvious correlation between chronic liver disease and the severity of COVID-19[56]. Hepatic steatosis (HS) is associated with elevated transaminases and the need for intubation, dialysis, and vasopressors. No connection between HS and jaundice or portal hypertension complications has been reported[57]. Liver steatosis can be used to predict COVID-19-related complications [58,59]. These previous findings indicate that males and elderly patients, as well as more severely ill patients, are highly likely to develop liver damage. COVID-19 patients with liver injury are more likely to be diagnosed with previous hypertension, coronary heart disease, and malignant tumors than patients without liver injury, and patients with liver abnormalities tend to have a higher incidence of heart injury, kidney injury, and SIRS. These findings indicate that liver biochemical abnormalities are closely related to heart damage, kidney damage, and SIRS and play an important role in COVID-19[60]. Increased bilirubin and AST/ALT ratios could predict the mortality of patients with liver cirrhosis[22]. Compared with the normal liver function group, patients with liver injury showed 3-fold greater AST levels, 19.27-fold greater mortality of patients with liver cirrhosis, and 116.7-fold greater risk of death. Factors significantly associated with liver damage included leukocytosis, lymphopenia, and male sex[60].

**MANAGEMENT AND TREATMENT OF LIVER INJURY IN COVID-19 PATIENTS**

A consistent treatment recommendation for liver function abnormalities in patients with COVID-19 has yet to be established. Liver function could provide clinicians with valuable information. Abnormal liver function could be used as an indicator to evaluate the prognosis of patients with COVID-19. Mishra et al[61] reviewed 348 patients diagnosed with COVID-19 and treated in a nursing center. Their liver injury is related to inflammation caused by COVID-19. Early and continuous monitoring of liver enzymes in patients with COVID-19 helps identify the changes in these patients in early disease stages. Another study found that the bilirubin level of dead patients with COVID-19 is significantly higher than that of patients discharged from hospitals. Early bilirubin monitoring can help detect severe and critical patients in early stages [40]. We can evaluate liver function to assess whether changes in the same in critical patients will influence their prognosis after identifying critical and non-critical patients [9]. The management of patients with COVID-19 and liver transplantation is complex, but strict prevention strategies are widely believed to be among the most important measures[62]. Dynamic changes in liver function may be significantly related to the severity and prognosis of COVID-19. Therefore, the relevant indicators should be closely monitored during hospitalization. Strengthening monitoring or individualized treatment in severe COVID-19 patients with previous liver disease and other pathological conditions is necessary. Compared with patients with normal liver function, patients with liver damage generally experience longer hospital stays and greater mortality[12].

Li et al[63] proposed that ALT, ALP, GT ALB, Pt, bilirubin, pre-ALB, blood cholesterol, and cholinesterase can contribute to the determination of the severity of liver injury and the evaluation of the regeneration ability of the liver. Therefore, an HBV DNA or HCV RNA nuclear acid test should be performed, and the status of patients should be determined to decide whether an antiviral treatment is needed. Albumin supple-ment and other necessary nutritional treatments should be given...
because of the close relationship between hypoalbuminemia and prognosis of patients with COVID-19[10]. Circulating albumin levels should also be maintained above 35 g/L, which is beneficial to the prognosis of patients[63]. AASLD Expert Panel Consensus Statement has pointed out that patients with cirrhosis, patients who have autoimmune hepatitis and are taking immune agents, and patients with a liver transplant are more susceptible to COVID-19 and develop severe symptoms and complications. As such, their liver function should be monitored[64]. For patients with liver injury, glycyrhizic acid drugs, reduced glutathione levels, ω-3 unsaturated fatty acids, and other drugs can be administered. Inhalation of interferon α-2b can reduce the elevation of ALT in patients during hospitalization. Nebulized inhalation of interferon α-2b can also inhibit SARS-CoV-2 and reduce the liver damage caused by this novel virus. The liver function of patients treated with drugs such as Rhetcivir, Lopinavir, and Etaracizumab should also be monitored continuously. If their liver function is abnormal, the administration of the related drugs should be stopped as soon as possible[11].

These findings suggest that effective control of COVID-19 could have protective effects in alleviating liver damage. COVID-19 patients with liver damage, especially severe patients, require rigorous liver function monitoring. In addition, appropriate drugs should be selected according to the patient’s condition, and medications that could damage liver function should be avoided.

CONCLUSION

The mechanism of liver injury caused by COVID-19 remains unclear. Inflammatory storms, hypoxia, drug factors, and viral damage to liver cells are known to participate in liver damage. However, the mechanisms through which these factors contribute to liver damage, the dynamic factors contributing specifically to liver damage, and which factors exacerbate liver damage remain unclear. More research is needed to clarify these issues. At present, no clear report on how to use drugs against liver damage for patients with COVID-19 is yet available. Whether patients with COVID-19 must be administered with treatment to protect their liver function at the onset of the disease or only after the relevant indicators become abnormal is unknown. However, reasonable treatment should be taken to avoid the failure of the liver and multiple organs in patients with liver damage. Such a strategy could decrease mortality in COVID-19 patients.

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REFERENCES

1 Pan L, Mu M, Yang P, Sun Y, Wang R, Yan J, Li P, Hu B, Wang J, Hu C, Jin Y, Niu X, Ping R, Du Y, Li T, Xu G, Hu Q, Tu L. Clinical Characteristics of COVID-19 Patients With Digestive Symptoms in Hubei, China: A Descriptive, Cross-Sectional, Multicenter Study. *Am J Gastroenterol* 2020; 115: 766-773 [PMID: 32287140 DOI: 10.14309/ajg.0000000000000620]

2 Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, Liu X, Shan H, Lei CL, Hui DSC, Du B, Li LJ, Zeng G, Yuen KY, Chen RC, Tang CL, Wang T, Chen PY, Xiang J, Li SY, Wang J, Liang ZJ, Peng YX, Wei L, Liu Y, Hu YH, Peng P, Wang JM, Liu JY, Chen Z, Li G, Zheng ZJ, Qu SJ, Luo J, Ye CJ, Zhu SY, Zhong NS; China Medical Treatment Expert Group for Covid-19. Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med* 2020; 382: 1708-1720 [PMID: 32109013 DOI: 10.1056/NEJMoa2002032]

3 Zhou F, Yu T, Du R, Fan G, Li Y, Yu Z, Xiang J, Wang Y, Song B, Gu X, Han L, Wei Y, Li H, Wu X, Xu J, Tu S, Zhang Y, Chen H, Cao B. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet* 2020; 395: 1054-1062 [PMID: 32171076 DOI: 10.1016/S0140-6736(20)30566-3]

4 Wu C, Chen X, Cai Y, Xia J, Zhou X, Xu S, Huang H, Zhang L, Du C, Zhang Y, Song J, Wang S, Chao Y, Yang Z, Xu J, Chen D, Xiong W, Xu L, Zhou F, Jiang J, Bai C, Zheng J, Song Y. Risk Factors Associated With Acute Respiratory Distress Syndrome and Death in Patients With Coronavirus Disease 2019 Pneumonia in Wuhan, China. *JAMA Intern Med* 2020; 180: 934-943 [PMID: 32167524 DOI: 10.1001/jamainternmed.2020.0994]
Zhou F et al. Liver injury in COVID-19

5 Arentz M, Yim E, Klaft F, Lokhandwala S, Riede FX, Chong M, Lee M. Characteristics and Outcomes of 21 Critically Ill Patients With COVID-19 in Washington State. JAMA 2020; 323: 1612-1614 [PMID: 32191259 DOI: 10.1001/jama.2020.4326]

6 Bhataraju PK, Ghassemiieh BJ, Nichols M, Kim R, Jerome KR, Nalla AK, Greninger AL, Pipavath S, Wurfel MM, Evans L, Kritik PA, West TE, Luks A, Gerbino A, Dale CR, Goldman JD, O'Mahony S, Mikaean C. Covid-19 in Critically Ill Patients in the Seattle Region - Case Series. N Engl J Med 2020; 382: 2012-2022 [PMID: 3227758 DOI: 10.1056/NEJMoa2004509]

7 Chu H, Bai T, Chen L, Hu L, Xiao L, Yao L, Zhu R, Niu X, Li Z, Zhang L, Han C, Song S, He Q, Zhao Y, Zha Q, Chen H, Schnabl B, Yang L, Hou X. Multicenter Analysis of Liver Injury Patterns and Mortality in COVID-19. Front Med (Lausanne) 2020; 7: 584342 [PMID: 33195339 DOI: 10.3389/fmedc.2020.584342]

8 Piano S, Dalbeni A, Vettore E, Benfaremo D, Mattioli M, Gambino CG, Famba V, Cerruti L, Mantovani A, Martini A, Luchetti MM, Serra R, Cattelan A, Vettor R, Angeli P. COVID-LIVER study group. Abnormal liver function tests predict transfer to intensive care unit and death in COVID-19. Liver Int 2020; 40: 2394-2406 [PMID: 32526083 DOI: 10.1111/Liv.14565]

9 Bashdash D, Olfatifar M, Hadaeigh F, Asadzadeh Aghdasi H, Zali MR. COVID-19 prognosis: what we know of the significance and prognostic value of liver-related laboratory parameters in SARS-CoV-2 infection. Gastroenterol Hepatol Bed Bench 2020; 13: 313-320 [PMID: 3244373 DOI: 10.22037/ghbhb.v13i4.2002]

10 Huang W, Li C, Wang Z, Wang H, Zhou N, Jiang N, Ni L, Zhang XA, Wang DW. Decreased serum albumin level indicates poor prognosis of COVID-19 patients: hepatic injury analysis from 2,623 hospitalized cases. Sci China Life Sci 2020; 63: 1678-1687 [PMID: 32567003 DOI: 10.1007/s11427-020-1733-4]

11 Cai Q, Huang D, Yu H, Zhu Z, Xia Z, Su Y, Li Z, Zhou G, Gou J, Qiu J, Sun Y, Liu Y, He Q, Chen J, Liu L, Xu L. COVID-19: Abnormal liver function tests. J Hepatol 2020; 73: 566-574 [PMID: 32298767 DOI: 10.1016/j.jhep.2020.04.006]

12 Fan Z, Chen L, Li J, Cheng X, Yang J, Tian C, Zhang Y, Huang S, Liu Z, Cheng J. Clinical Features of COVID-19-Related Liver Functional Abnormality. Clin Gastroenterol Hepatol 2020; 18: 1561-1566 [PMID: 32283325 DOI: 10.1016/j.cgh.2020.04.002]

13 Wu Y, Li H, Guo X, Yoshida EM, Mendez-Sanchez N, Levi Sandri GB, Teschke R, Romeiro FG, Shukla A, Qi X. Incidence, risk factors, and prognosis of abnormal liver biochemical tests in COVID-19 patients: a systematic review and meta-analysis. Hepatol Int 2020; 14: 621-637 [PMID: 32710250 DOI: 10.1007/s12072-020-10074-6]

14 Wu J, Liu J, Zhao X, Liu C, Wang W, Wang D, Xu W, Zhang C, Yu J, Jiang B, Cao H, Li L. Clinical Characteristics of Imported Cases of Coronavirus Disease 2019 (COVID-19) in Jiangsu Province: A Multicenter Descriptive Study. Clin Infect Dis 2020; 71: 706-712 [PMID: 32109279 DOI: 10.1093/cid/cia199]

15 Wang H, Qu P, Liu J, Wang F, Zhao Q. The liver injury and gastrointestinal symptoms in patients with Coronavirus Disease 19: A systematic review and meta-analysis. Clin Res Hepatol Gastroenterol 2020; 44: 653-661 [PMID: 32418852 DOI: 10.1016/j.clinre.2020.04.012]

16 Da BL, Mitchell RA, Lee BT, Perumalswami P, Im GY, Agarwal R, Schiano TD, Dieterich D, Saberi B. Kinetic patterns of liver enzyme elevation with COVID-19 in the USA. Eur J Hepatology 2020; 32: 1466-1469 [PMID: 32501877 DOI: 10.1016/j.ejhep.2020.10074-6]

17 Da BL, Kushner T, El Halabi M, Paka P, Khalid M, Uberoi A, Lee BT, Perumalswami PV, Rutledge SM, Schiano TD, Friedman S, Saberi B. Liver Injury in Hospitalized Patients with COVID-19 Correlates with Hyper Inflammatory Response and Elevated IL-6. Hepatol Commun 2020; 4: 33204941 DOI: 10.1002/hep4.1631]

18 Fu L, Fei J, Xu S, Xiang HX, Xiang Y, Hu B, Li MD, Liu FF, Li Y, Li XY, Zhao H, Xu DX. Liver Dysfunction and Its Association with the Risk of Death in COVID-19 Patients: A Prospective Cohort Study. J Clin Transl Hepatol 2020; 8: 246-254 [PMID: 33083246 DOI: 10.14218/JCTH.2020.00043]

19 Lin Y, Yuan J, Long Q, Hu J, Deng H, Zhao Z, Chen J, Lu M, Huang A. Patients with SARS-CoV-2 and HBV co-infection are at risk of greater liver injury. Genes Dis 2020; 32: 3225036 DOI: 10.1111/Liv.14565]

20 Zou X, Fang M, Li S, Wu L, Gao B, Gao H, Ran X, Bian Y, Li R, ShanshanYu, Ling J, Li D, Tian D, Huang J. Characteristics of Liver Function in Patients With SARS-CoV-2 and Chronic HBV Coinfection. Clin Gastroenterol Hepatol 2021; 19: 597-603 [PMID: 32553907 DOI: 10.1016/j.cgh.2020.06.017]

21 Ji D, Qin E, Xu J, Zhang D, Cheng G, Wang Y, Lau G. Non-alcoholic fatty liver diseases in patients with COVID-19: A retrospective study. J Hepatol 2020; 73: 451-453 [PMID: 32278005 DOI: 10.1016/j.jhep.2020.03.044]

22 Sarin SK, Choudhury A, Lau GK, Zheng MH, Ji D, Abd-Elsalam S, Hwang J, Qi X, Cua HH, Suh JI, Park JG, Putcharoen O, Kwaedeew O, Piratsivath T, Taweeprertasuk S, Park S, Wejnarumern S, Payawal DA, Baatarkhuu O, Ahn SH, Yeo CD, Alonzo UR, Chinhuyar T, Lohu JM, Yokosuka O, Jafri W, Tan S, Sui LI, Tanwanseed T, Gani R, Anand L, Esmail ES, Khamif M, Alam S, Lin CY, Chuan WL, Soin AS, Gark HK, Kalista K, Batsukh B, Purnomo HD, Dara VP, Rathi P, Al Mahtab M, Shukla A, Sharma MK, Omata M. APASL COVID Task Force, APASL COVID Liver Injury Spectrum Study (APCOCIS Study-NCT 04345640). Pre-existing liver disease is associated with poor outcome in patients with SARS-CoV2 infection; The APASL Study (APASL COVID-19 Liver Injury Spectrum Study). Hepatol Int 2020; 14: 690-700 [PMID: 32623632 DOI: 10.1111/1478-3231.13739]
factors of liver injury in COVID-19: a retrospective cohort study from Wuhan, China.
Ding H, Xing M, Han M, Luo X, Chen T, Guo W, Xi D, Ning Q. Clinical characteristics and risk
Wang M
Target Ther
10.3389/fimmu.2020.00827
Disease 2019 (COVID-19).
Wu Y, Chen Y. Reduction and Functional Exhaustion of T Cells in Patients With Coronavirus
Diao B
10.1101/2020.04.15.20067157
City: a prospective cohort study.
Jin Q, Wang J, Cao B. Clinical features of patients infected with 2019 novel coronavirus in Wuhan,
Wei Y, Wu W, Xie X, Yin W, Li H, Liu M, Xiao Y, Gao H, Guo L, Li H, Yang J, Jiang R, Gao Z,
Huang C
10.1093/cid/ciaa629
Asymptomatic Cohort of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infected
Han H
10.1038/s12072-020-10072-8
Transmission of COVID-19 during the incubation period demonstrating strong infectivity in a cluster
Huang L
[PMID: 32183930] DOI: 10.2807/1560-7917.ES.2020.25.10.2000180
Nishiura H, Kobayashi T, Miyama T, Suzuki A, Jung SM, Hayashi K, Kinoshita R, Yang Y, Yuan B,
Akhmetzhanov AR, Linton NM. Estimation of the asymptomatic ratio of novel coronavirus infections
COVID-19). Int J Infect Dis 2020; 94: 154-155 [PMID: 32179137] DOI: 10.1016/j.ijid.2020.03.020
He X, Lau EHY, Wu P, Deng X, Wang J, Hao X, Lau YC, Wong JY, Guan Y, Tan X, Mo X, Chen Y,
Liao B, Chen W, Hu F, Zhang Q, Zhong M, Wu Y, Zhao L, Zhang F, Cowling BJ, Li F, Leung GM. Temporal
dynamics in viral shedding and transmissibility of COVID-19. Nat Med 2020; 26: 672-675
[PMID: 32296168] DOI: 10.1038/s41591-020-08869-5
Huang L, Zhang X, Wei Z, Zhang L, Xu J, Liang P, Xu Y, Zhang C, Xu A. Rapid asymptomatic
transmission of COVID-19 during the incubation period demonstrating strong infectivity in a cluster
of youngsters aged 16-23 years outside Wuhan and characteristics of young patients with COVID-19: A
prospective contact-tracing study. J Infect 2020; 80: e1-e13 [PMID: 32283156] DOI: 10.1016/j.jinf.2020.03.006
Bai Y, Yao L, Wei T, Tian F, Jin DY, Chen L, Wang M. Presumed Asymptomatic Carrier Transmission of COVID-19. JAMA 2020; 323: 1406-1407 [PMID: 32083643] DOI: 10.1001/jama.2020.2565
Uhm JS, Ahn JY, Hyun J, Sohn Y, Kim JH, Jeong SJ, Ku NS, Choi JY, Park YK, Yi HS, Park SK, Kim BO, Kim H, Choi J, Kang SM, Choi YH, Yoon HK, Jung S, Kim HN, Yoon JS, Park YS. Patterns of viral clearance in the natural course of asymptomatic COVID-19: Comparison with symptomatic non-severe COVID-19. Int J Infect Dis 2020; 99: 279-285 [PMID: 32763446] DOI: 10.1016/j.ijid.2020.07.070
Wang Y, He Y, Tong J, Qin Y, Xie T, Li J, Xiang J, Cui Y, Higgs ES. Characterization of an
Asymptomatic Cohort of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Infected
Individuals Outside of Wuhan, China. Clin Infect Dis 2020; 71: 2132-2138 [PMID: 32442265] DOI: 10.1093/cid/ciaa629
Chen J, Han T, Huang M, Yang Y, Shang F, Zheng Y, Zhao W, Luo L, Han X, Lin A, Zhao H, Gu Q, Shi Y, Li J, Xu X, Liu K, Deng Y, Jia E, Cao Q. Clinical characteristics of asymptomatic carriers of novel coronavirus disease 2019: A multi-center study in Jiangsu Province. Virulence 2020; 11: 1557-1568 [PMID: 33136892] DOI: 10.1080/21505594.2020.1840122
Han H, Xu Z, Cheng X, Zhong Y, Yuan L, Wang F, Li Y, Liu F, Jiang Y, Zhu C, Xia Y. Descriptive,
Retrospective Study of the Clinical Characteristics of Asymptomatic COVID-19 Patients. mSphere 2020; 5 [PMID: 33030689] DOI: 10.1128/mSphere.00922-20
Xu T, Huang R, Zhu L, Wang J, Cheng J, Zhang B, Zhao H, Chen K, Shao H, Zhu C, Wu C, Liu L. Epidemiological and clinical features of asymptomatic patients with SARS-CoV-2 infection. J Med Viral 2020; 92: 1884-1889 [PMID: 32346783] DOI: 10.1002/jmv.25944
Mihara M, Hashizume M, Yoshida H, Suzuki M, Shima N. IL-6/IL-6 receptor system and its role in physiological and pathological conditions. Clin Sci (Lond) 2012; 122: 143-159 [PMID: 22092686] DOI: 10.1042/CS20110340
Di Mauro G, Scavone C, Rafaniello C, Rossi F, Capuano A. SARS-CoV-2 infection: Response of human immune system and possible implications for the rapid test and treatment. Int Immunopharmacol 2020; 84: 106519 [PMID: 32311668] DOI: 10.1016/j.intimp.2020.106519
Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, Fan G, Xu J, Gu X, Cheng Z, Yu T, Xia J, Wei Y, Wu W, Xie X, Yin W, Li H, Liu M, Xiao Y, Gao H, Guo L, Xi L, Wei G, Jiang R, Gao Z, Jin Q, Wang J, Cao B. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020; 395: 497-506 [PMID: 31986264] DOI: 10.1016/S0140-6736(20)30183-5
Cummins MJ, Baldwin MR, Abrams D, Jacobson SD, Meyer BJ, Balough EM, Aaron JG, Claassen J, Rabbanie LE, Hasite J, Hochman BR, Salazar-Schicchi J, Yip NH, Brodie D, O'Donnell MR. Epidemiology, clinical course, and outcomes of critically ill adults with COVID-19 in New York City: a prospective cohort study. medRxiv 2020 [PMID: 32511638] DOI: 10.1101/2020.04.15.20067157
Diao B, Wang C, Tan Y, Chen X, Liu Y, Ning L, Chen L, Li M, Wang G, Yuan Z, Feng Z, Zhang Y, Wu Y, Chen Y. Reduction and Functional Exhaustion of T Cells in Patients With Coronavirus Disease 2019 (COVID-19). Front Immunol 2020; 11: 827 [PMID: 32425950] DOI: 10.3389/fimmu.2020.00827
Liao S, Zhan K, Gan L, Bai Y, Li J, Yuan G, Cai Y, Zhang A, He S, Mei Z. Inflammatory cytokines,
T lymphocyte subsets, and ronivimab involved in liver injury of COVID-19 patients. Signal Transduct Target Ther 2020; 8: 255 [PMID: 33130825] DOI: 10.1038/s41392-020-00436-0
Wang M, Yan W, Qi W, Wu D, Zhu L, Li W, Wang X, Ma K, Ni M, Xu D, Wang H, Chen G, Yu H, Ding H, Xing M, Han M, Luo X, Chen T, Guo W, Xi D, Ning Q. Clinical characteristics and risk factors of liver injury in COVID-19: a retrospective cohort study from Wuhan, China. Hepatol Int
Liver injury in COVID-19

WJCC | https://www.wjgnet.com

41 Lei F, Liu YM, Zhou F, Qin JJ, Zhang P, Zhu L, Zhang XJ, Cai J, Lin L, Ouyang S, Wang X, Yang C, Cheng X, Liu W, Li H, Xie J, Wu B, Luo H, Xiao F, Chen J, Tao L, Cheng G, She ZG, Zhou J, Wang H, Lin J, Luo P, Fu S, Ye P, Xiao B, Mao W, Liu L, Yan Y, Chen G, Huang X, Zhang BH, Yuan Y. Longitudinal Association Between Markers of Liver Injury and Mortality in COVID-19 in China. Hepatology 2020; 72: 389-398 [PMID: 32359177 DOI: 10.1002/hep.31301]

42 Lan NT, Thu NT, Barrail-Tran A, Duc NH, Lan NN, Laureillard D, Lien TT, Borland L, Quillet C, Connolly C, Lagarde D, Pym A, Lienhardt C, Dang NH, Taburet AM, Harrison JD. Randomised pharmacokinetic trial of rituximab with lopinavir/ritonavir-antiretroviral therapy in patients with HIV-associated tuberculosis in Vietnam. PLoS One 2014; 9: e84866 [PMID: 24465443 DOI: 10.1371/journal.pone.0084866]

43 Jiang S, Wang R, Li L, Hong D, Ru R, Rao Y, Miao J, Chen N, Wu X, Ye Z, Hu Y, Xie M, Zuo M, Lu X, Qiu Y, Liang T. Liver Injury in Critically Ill and Non-critically Ill COVID-19 Patients: A Multicenter, Retrospective, Observational Study. Front Med (Lausanne) 2020; 7: 347 [PMID: 32565222 DOI: 10.3389/fmed.2020.00347]

44 Larson AM. Acetaminophen hepatotoxicity. Clin Liver Dis 2007; 11: 525-548, vi [PMID: 17723918 DOI: 10.1016/j.cld.2007.06.006]

45 Campochiaro C, Della-Torre E, Cavalli G, De Luca G, Ripa M, Boffini N, Tomelleri A, Baldissera E, Rovere-Querini P, Ruggieri A, Monti G, De Cobelli F, Zangrillo A, Tresoldi M, Castagna A, Dagna L, TOCI-RAF Study Group. Efficacy and safety of tocilizumab in severe COVID-19 patients: a single-centre retrospective cohort study. Eur J Intern Med 2020; 76: 43-49 [PMID: 32465297 DOI: 10.1016/j.ejim.2020.05.021]

46 Grein J, Ohmagari N, Shin D, Diaz G, Asperges E, Castagna A, Feldt T, Green G, Green ML, Lescure FX, Nicastri E, Oda R, Yu K, Quiros-Roldan E, Studemeister A, Redini S, Ahmed S, Bernett J, Chelliah D, Chen D, Chihara S, Cohen SH, Cunningham J, D'Arminio Monforte A, Ismail S, Kato H, Lapadula G, L'Her E, Maeno T, Majumder S, Massari M, Mora-Rillo M, Mutoh Y, Nguyen D, Verweij E, Zoufaly A, Osinusi AO, DeZure A, Zhao Y, Zhong L, Chokkalingam A, Elboudwarej E, Telep L, Timbs L, Henne I, Sellers S, Cao H, Tan SK, Winterkorn L, Desai P, Mera R, Gaggero A, Myers RP, Brainard DM, Childs R, Flanigan T. Compassionate Use of Remdesivir for Patients with Severe Covid-19. N Engl J Med 2020; 383: 2327-2336 [PMID: 32275812 DOI: 10.1056/NEJMoa2007016]

47 Wang Y, Zhang D, Du G, Du R, Zhao J, Jin Y, Fu S, Gao L, Cheng Z, Lu Q, Hu Y, Luo G, Wang K, Lu Y, Li H, Wang S, Ruan S, Yang C, Mei C, Wang Y, Ding D, Wu F, Tang X, Ye X, Ye Y, Liu B, Yang J, Yin W, Wang A, Fan G, Zhou F, Liu Z, Gu X, Xu J, Shang L, Zhang Y, Cao L, Guo T, Wan Y, Qin H, Jiang J, Jaki T, Hayden FG, Horby PW, Cao B, Wang C. Remdesivir in adults with severe COVID-19: a randomised, double-blind, placebo-controlled, multicentre trial. Lancet 2020; 395: 1569-1578 [PMID: 32423584 DOI: 10.1016/s0140-6736(20)31022-9]

48 Wang Y, Liu S, Liu H, Li W, Lin F, Jiang L, Li X, Xu P, Zhang L, Zhao L, Cao Y, Kang J, Yang J, Li L, Liu X, Li Y, Nie R, Mu J, Lu F, Zhao S, Lu J, Zhao J. SARS-CoV-2 infection of the liver directly contributes to hepatic impairment in patients with COVID-19. J Hepatol 2020; 73: 807-816 [PMID: 3237830 DOI: 10.1016/j.jhep.2020.05.002]

49 Yeo C, Kaushal S, Yeo D. Enteric involvement of coronaviruses: is fecal-oral transmission of SARS-CoV-2 possible? Lancet Gastroenterol Hepatol 2020; 5: 335-337 [PMID: 32087098 DOI: 10.1016/S2468-1253(20)30048-0]

50 Martinus RB, Ritter JM, Matkovic E, Gary J, Bollweg BC, Bullock H, Goldsmith CS, Silva-Flannery L, Seixas JN, Reagan-Steiner S, Uyeiki T, Denison A, Bhatnagar J, Shieh WJ, Zaki SR. COVID-19 Pathology Working Group. Pathology and Pathogenesis of SARS-CoV-2 Associated with Fatal Coronavirus Disease, United States. Emerg Infect Dis 2020; 26: 2005-2015 [PMID: 32437316 DOI: 10.3201/eid2609.200209]

51 Hoffmann M, Kleine-Weber H, Schroeder S, Krüger N, Herrler T, Fricheisen S, Schiergens TS, Herrler G, Wu NH, Nitsche A, Müller MA, Drosten C, Pöhlmann S. SARS-CoV-2 Cell Entry Depends on ACE2 and TMPRSS2 and Is Blocked by a Clinically Proven Protease Inhibitor. Cell 2020; 181: 271-280. e8 [PMID: 32142651 DOI: 10.1016/j.cell.2020.02.052]

52 Lagana SM, Kadose S, Iuga AC, Lee MJ, Fazzolari L, Rennotti HE, Del Portillo A, De Michele S, de Gonzalez AK, Saqi A, Khairallah P, Chong AM, Park H, Uhlmann AC, LeKwotch JH, Verna EC. Hepatic pathology in patients dying of COVID-19: a series of 40 cases including clinical, histological, and virologic data. Mod Pathol 2020; 33: 2147-2155 [PMID: 32792598 DOI: 10.1038/s41379-020-06649-x]

53 Zhang C, Shi L, Wang FS. Liver injury in COVID-19: management and challenges. Lancet Gastroenterol Hepatol 2020; 5: 428-430 [PMID: 32145190 DOI: 10.1016/S2468-1253(20)30057-1]

54 Targher G, Mantovani A, Byrne CD, Wang XB, Yan HD, Sun QF, Pan KH, Zheng K, Chen YP, Esam M, George J, Zheng MH. Detrimental effects of metabolic dysfunction-associated fatty liver disease and increased neutrophil-to-lymphocyte ratio on severity of COVID-19. Diabetes Metab 2020; 46: 505-507 [PMID: 32505652 DOI: 10.1016/j.diabet.2020.06.001]

55 Li C, Chen Q, Wang J, Lin H, Lin Y, Lin J, Peng F, Chen J, Yang Z. Clinical characteristics of chronic liver disease with coronavirus disease 2019 (COVID-19): a cohort study in Wuhan, China. Aging (Albany NY) 2020; 12: 15938-15945 [PMID: 32853561 DOI: 10.18632/aging.105632]

56 Bangash MN, Patel J, Parikh D. COVID-19 and the liver: little cause for concern. Lancet Gastroenterol Hepatol 2020; 5: 529-530 [PMID: 32303680 DOI: 10.1016/S2468-1253(20)30084-4]
Effenberger M, Grander C, Fritsche G, Bellmann-Weiler R, Hartig F, Wildner S, Seiwald S, Adolph TE, Zoller H, Weiss G, Tilg H. Liver stiffness by transient elastography accompanies illness severity in COVID-19. BMJ Open Gastroenterol 2020; 7 [PMID: 32665398 DOI: 10.1136/bmjgast-2020-000442]

Chen VL, Hawa F, Berinstein JA, Reddy CA, Kassab I, Platt KD, Hsu CY, Steiner CA, Louissaint J, Gunaratnam NT, Sharma P. Hepatic Steatosis Is Associated with Increased Disease Severity and Liver Injury in Coronavirus Disease-19. Dig Dis Sci 2020 [PMID: 32980956 DOI: 10.1007/s10620-020-06618-3]

Gao F, Zheng KI, Wang XB, Yan HD, Sun QF, Pan KH, Wang TY, Chen YP, George J, Zheng MH. Metabolic associated fatty liver disease increases coronavirus disease 2019 disease severity in non-diabetic patients. J Gastroenterol Hepatol 2021; 36: 204-207 [PMID: 32436622 DOI: 10.1111/jgh.15112]

Huang H, Chen S, Li H, Zhou XL, Dai Y, Wu J, Zhang J, Shao L, Yan R, Wang M, Wang J, Tu Y, Ge M. The association between markers of liver injury and clinical outcomes in patients with COVID-19 in Wuhau. Aliment Pharmacol Ther 2020; 52: 1051-1059 [PMID: 32697870 DOI: 10.1111/apt.15962]

Mishra K, Naftouj S, Gorgis S, Ibrahim H, Gill S, Fadel R, Chatfield A, Tang A, Salgia R. Liver Injury as a Surrogate for Inflammation and Predictor of Outcomes in COVID-19. Hepatol Commun 2021; 5: 24-32 [PMID: 33437898 DOI: 10.1002/hep.4.1586]

Huang JF, Zheng KI, George J, Gao HN, Wei RN, Yan HD, Zheng MH. Fatal outcome in a liver transplant recipient with COVID-19. Am J Transplant 2020; 20: 1907-1910 [PMID: 32277591 DOI: 10.1111/ajt.15909]

Li Y, He F, Zhou N, Wei J, Ding Z, Wang L, Chen P, Guo S, Zhang B, Wan X, Zhu W; Multidisciplinary Team for COVID-19. Organ function support in patients with coronavirus disease 2019: Tongji experience. Front Med 2020; 14: 232-248 [PMID: 32405974 DOI: 10.1007/s11684-020-0774-9]

Fix OK, Hameed B, Fontana RJ, Kwok RM, McGuire BM, Mulligan DC, Pratt DS, Russo MW, Schilsky ML, Verna EC, Loomba R, Cohen DE, Bezerra JA, Reddy KR, Chung RT. Clinical Best Practice Advice for Hepatology and Liver Transplant Providers During the COVID-19 Pandemic: AASLD Expert Panel Consensus Statement. Hepatology 2020; 72: 287-304 [PMID: 32298473 DOI: 10.1002/hep.31281]
