International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Stem Cell Treatment in End-Stage Liver Cirrhosis Clinical and Biochemical Improvement in a Transplant - Advised Patient: A Case Report

Naman Somani[1], Divyang Patel[2]

Corresponding Author Email: *naman[at]cellstar.in*

Abstract: ***Liver cirrhosis, a progressive and irreversible condition characterized by hepatocellular dysfunction, fibrosis, and impaired regenerative capacity, is a major cause of morbidity and mortality worldwide. In advanced stages, patients frequently present with jaundice, ascites, and hyperbilirubinemia, with liver transplantation remaining the only definitive treatment. However, organ scarcity, cost, and surgical risk significantly limit its accessibility. The disease is driven by chronic inflammation, oxidative stress, and activation of hepatic stellate cells leading to fibrosis, with pro-inflammatory cytokines such as TNF-α, IL-6, and TGF-β playing central roles in disease progression. Conventional management strategies focus on symptomatic relief and suppression of inflammation, but these do not reverse underlying hepatic injury. In recent years, mesenchymal stem cells (MSCs) and MSC-derived biologics have emerged as promising therapeutic options for chronic liver disease. MSCs mediate hepatic repair through multiple mechanisms, including immunomodulation, anti-fibrotic activity, angiogenesis, paracrine signaling, and stimulation of endogenous hepatocyte proliferation. The paracrine factors secreted by MSCs—such as cytokines, growth factors, and extracellular vesicles—act on the hepatic microenvironment to suppress inflammation, attenuate stellate cell activation, and promote regeneration. Here, we report a case of a patient with advanced liver cirrhosis who was originally advised to have a liver transplantation but instead received Stem cell treatment. The patient presented with severe hyperbilirubinemia (total bilirubin: 12.30 mg/dL) prior to treatment. Following three cycles of treatments, serum bilirubin levels decreased markedly to 6.50 mg/dL after the second cycle and further to 4.60 mg/dL after the third cycle. Clinically, the patient reported improved appetite, energy, and quality of life, with resolution of jaundice. Importantly, the patient was no longer considered for immediate liver transplantation. Our findings demonstrate that Stem cell treatment may provide a regenerative and clinically meaningful alternative to transplantation by reversing liver dysfunction and improving biochemical outcomes. These observations align with emerging evidence supporting the use of MSC-based treatments in chronic liver disease.***

Keywords: Liver cirrhosis, End-stage liver disease, Stem cell therapy, Mesenchymal stem cells (MSCs), Exosomes, Hepatic regeneration, Liver fibrosis, Fibrosis reversal, Cellular therapy, Regenerative medicine, Hepatic stellate cells (HSCs), Anti-fibrotic activity, Immunomodulation, Cytokines (IL-6, TNF-α, TGF-β), Growth factors (HGF, VEGF, IGF-1, EGF)

1. Introduction

Liver cirrhosis, a progressive chronic liver disease, is among the leading causes of morbidity and mortality worldwide, affecting more than 2 million people annually [3]. It represents the final common stage of a variety of chronic liver injuries including viral hepatitis, alcohol-induced liver damage, metabolic syndromes, autoimmune hepatitis, and non-alcoholic fatty liver disease. Clinically, cirrhosis is characterized by diffuse hepatic fibrosis, regenerative nodule formation, and progressive architectural distortion of the liver, ultimately leading to complications such as portal hypertension, coagulopathy, hepatic encephalopathy, ascites, and hepatocellular carcinoma [27]. The disease is often insidious in onset but once decompensated, the prognosis is poor. For decades, liver transplantation has remained the only definitive therapeutic option, although donor shortages, high costs, surgical risks, and the need for lifelong immunosuppression limit its applicability to most patients [21].

At the molecular level, liver cirrhosis is marked by chronic inflammation and fibrogenesis mediated through the activation of hepatic stellate cells (HSCs). Upon liver injury, HSCs become activated, proliferate, and secrete excessive extracellular matrix (ECM) proteins, especially type I collagen, which disrupts the normal liver architecture. Several pro-inflammatory cytokines and growth factors, including transforming growth factor-β (TGF-β), platelet-derived growth factor (PDGF), tumor necrosis factor-alpha (TNF-α), and interleukin-6 (IL-6), have been implicated in promoting HSC activation and fibrosis [6]. In addition, the interplay between the innate and adaptive immune systems exacerbates chronic liver inflammation. Activated T cells, Kupffer cells, and infiltrating monocytes release cytokines and chemokines that further drive fibrogenesis and hepatocyte apoptosis [10].

Conventional therapies aim to halt disease progression by addressing the underlying causes, such as antiviral therapy in hepatitis or abstinence from alcohol. However, these strategies rarely reverse established cirrhosis. Despite advances in antifibrotic drug development, there remains no universally effective pharmacological treatment for reversing liver fibrosis [5]. Thus, the urgent need for alternative regenerative and disease-modifying therapies persists.

Mesenchymal stem cells (MSCs) have emerged as a promising candidate in this regard. MSCs are multipotent progenitor cells that can be isolated from bone marrow, adipose tissue, umbilical cord, placenta, dental pulp, and other sources. They are characterized by their spindle-shaped fibroblast-like morphology, adherence to plastic under standard culture conditions, and the expression of specific surface markers including CD73, CD90, and CD105, with absence of hematopoietic markers such as CD34, CD45, and CD14 [3]. MSCs exert a wide spectrum of therapeutic effects through mechanisms of immunomodulation, anti-inflammation, anti-fibrosis, anti-apoptosis, and pro-

angiogenesis. They mediate these activities primarily via paracrine signaling, secreting a variety of bioactive molecules such as growth factors, cytokines, chemokines, extracellular vesicles, and exosomes [22]. These secreted factors suppress the activation of HSCs, downregulate pro-fibrotic cytokines, enhance hepatocyte regeneration, and restore the immune balance within the diseased liver [16].

Furthermore, MSCs have demonstrated the ability to modulate both innate and adaptive immune responses. They inhibit T-cell proliferation, reduce dendritic cell activation, and upregulate regulatory T cells. Their secretion of immunomodulatory molecules such as interleukin-10 (IL-10), prostaglandin E2 (PGE2), indoleamine 2,3-dioxygenase (IDO), and nitric oxide (NO) contributes to their capacity to reduce inflammation and fibrosis. Importantly, preclinical and clinical studies have shown that MSC administration in cirrhotic patients leads to improved liver function parameters, reduction of fibrosis, and enhancement of quality of life [19,30].

In the present case, we describe a patient diagnosed with advanced liver cirrhosis who was initially advised to undergo liver transplantation. Instead, the patient received a stem cell–based regenerative treatment utilizing mesenchymal stem cells (MSCs) and their secreted exosomes. Following therapy, the patient demonstrated significant improvement in bilirubin levels, liver function parameters, and overall well-being. Remarkably, the patient was able to avoid liver transplantation and reported enhanced energy levels and quality of life. This case highlights the therapeutic potential of stem cells and exosome in managing advanced cirrhosis and provides supportive clinical evidence for their application as a viable alternative to liver transplantation.

2. Case Presentation

A 51-year-old male patient, diagnosed with advanced liver cirrhosis, presented to our hospital approximately two months ago. The patient reported a long-standing history of progressive liver dysfunction, which had been gradually worsening over the years. At the time of presentation, he complained of persistent fatigue, generalized weakness, loss of appetite, and yellowish discoloration of the skin and sclera. He also experienced reduced stamina and difficulty performing routine daily activities, which significantly affected his quality of life.

The patient had previously been evaluated at a tertiary hospital, where he underwent a detailed hepatology assessment. Based on clinical and biochemical parameters, he was diagnosed with advanced cirrhosis with severe hyperbilirubinemia. His treating physicians strongly recommended liver transplantation as the only definitive treatment option. However, considering the financial, logistic, and health-related challenges of transplantation, along with the associated risks such as graft rejection and life-long immunosuppression, the patient and his family were keen to explore advanced regenerative alternatives. After detailed counseling and explanation of the proposed therapy, written informed consent was obtained, and the patient was enrolled for stem cell and exosome-based therapy at our clinic.

For the regenerative treatment, we utilized donor-derived adipose tissue mesenchymal stem cells (MSCs) and amniotic fluid derived exosomes. The MSCs were isolated from healthy donors and expanded under GMP-compliant and ISO-certified in-house laboratory conditions. In total, 200 million viable MSCs were prepared for the entire therapeutic course. In addition, exosomes were isolated from donor amniotic fluid using a tangential flow filtration (TFF) system, ensuring high purity, stability, and clinical-grade quality. Approximately 90 billion exosomes were administered to the patient across the treatment duration.
The treatment was delivered intravenously (IV), which was chosen as the optimal route to ensure systemic bioavailability, efficient homing of MSCs to sites of liver injury, and widespread distribution of exosomes to exert their paracrine and immunomodulatory effects. The intravenous administration was well tolerated, and no infusion-related complications were observed during the procedure or in the subsequent monitoring period.

The patient underwent treatment over a one-month period, during which a combination of stem cells and exosomes was administered in a stepwise manner. Regular monitoring was carried out on a weekly basis, both clinically and through laboratory investigations. The clinical assessment focused on fatigue, energy levels, appetite, and overall physical well-being, while biochemical evaluation was primarily directed toward bilirubin levels, given its significance in liver disease progression and prognosis.

During the course of treatment, the patient reported steady symptomatic improvements. Within the first two weeks, he noted a reduction in fatigue, better appetite, and improved energy, allowing him to engage more actively in routine activities. By the fourth week, his jaundice had visibly reduced, and he expressed that he felt “much lighter and energetic” compared to his condition prior to treatment.

Biochemical parameters strongly corroborated the clinical improvements. At baseline, prior to treatment initiation, the patient’s total bilirubin was 12.3 mg/dL, which was significantly above the normal range and reflective of advanced liver dysfunction. After two weeks of therapy, his bilirubin levels decreased to 6.50 mg/dL, demonstrating a substantial improvement. At a follow-up evaluation conducted one month after initiating treatment, his bilirubin stabilized at 4.60 mg/dL.

The progressive reduction in bilirubin levels directly mirrored the patient’s symptomatic recovery. Importantly, following the completion of therapy, the patient no longer required a liver transplant, which had previously been deemed essential. On follow-up, he described feeling “more energetic, healthier, and capable of resuming daily life without major limitations.” No adverse events or complications were reported throughout the treatment and observation period, highlighting both the safety and efficacy of the intervention.

This case not only demonstrates the potential of intravenous MSC and exosome-based therapy in reversing hyperbilirubinemia and improving clinical status in advanced

liver cirrhosis but also underscores its promise as a viable alternative to liver transplantation in select patients.

Clinical outcome:

The patient reported dramatic improvement in overall energy, reduced jaundice, better appetite, and improved ability to perform daily activities. He specifically stated:

"Before therapy, I was told I needed a liver transplant. After the Stem Cells treatment, I feel like I got my life back. My energy is much better, and I can do things I couldn't imagine before."

At follow-up, he was no longer considered for immediate liver transplantation and continued to remain stable under periodic monitoring.

3. Discussion

Roles of mesenchymal stem cells (MSCs) in tissue repair, immunomodulation, and organ regeneration have been extensively investigated in both preclinical and clinical studies. In the context of liver diseases, MSCs have demonstrated therapeutic effects in several experimental models of hepatic injury, as well as in patients with advanced liver cirrhosis. These effects are largely attributed to the paracrine activity of MSCs, whereby they secrete bioactive molecules and extracellular vesicles, including exosomes, which modulate the host immune microenvironment, reduce inflammation, and promote regeneration of hepatocytes and restoration of liver function.

Preclinical studies using carbon tetrachloride (CCl_4)–induced liver injury and bile duct ligation (BDL) models have consistently demonstrated that infusion of MSCs can attenuate hepatic fibrosis, reduce collagen deposition, and improve liver function by modulating T-cell activity, suppressing pro-inflammatory cytokines, and enhancing hepatocyte proliferation [11,12,29]. Exosomes derived from MSCs have also been shown to exert antifibrotic effects through inhibition of hepatic stellate cell activation and induction of apoptosis in activated stellate cells, which are key mediators of fibrosis progression [13]. In a few clinical trials, infusion of bone marrow– and adipose-derived MSCs in cirrhotic patients resulted in significant reductions in serum bilirubin levels and improvements in Child-Pugh and MELD scores, suggesting real translational potential [2,17,24].

In our present case, we observed a striking therapeutic effect following the administration of donor-derived adipose MSCs and amniotic fluid–derived exosomes in a patient with advanced liver cirrhosis who had been initially advised to undergo liver transplantation. The treatment regimen consisted of 200 million viable MSCs and 90 billion exosomes, administered intravenously over a period of one month. The intravenous route was chosen to ensure systemic bioavailability and targeted delivery to the injured liver. This therapeutic approach resulted in a steady decline in bilirubin levels, with total bilirubin decreasing from 12.3 mg/dL at baseline to 6.5 mg/dL after the second cycle and further improving to 4.6 mg/dL after the third cycle. These biochemical improvements were paralleled by marked symptomatic recovery, including resolution of jaundice, improved energy levels, and overall enhanced quality of life. The patient also expressed positive feedback, emphasizing improved vitality and relief from the burden of transplantation-related uncertainty.

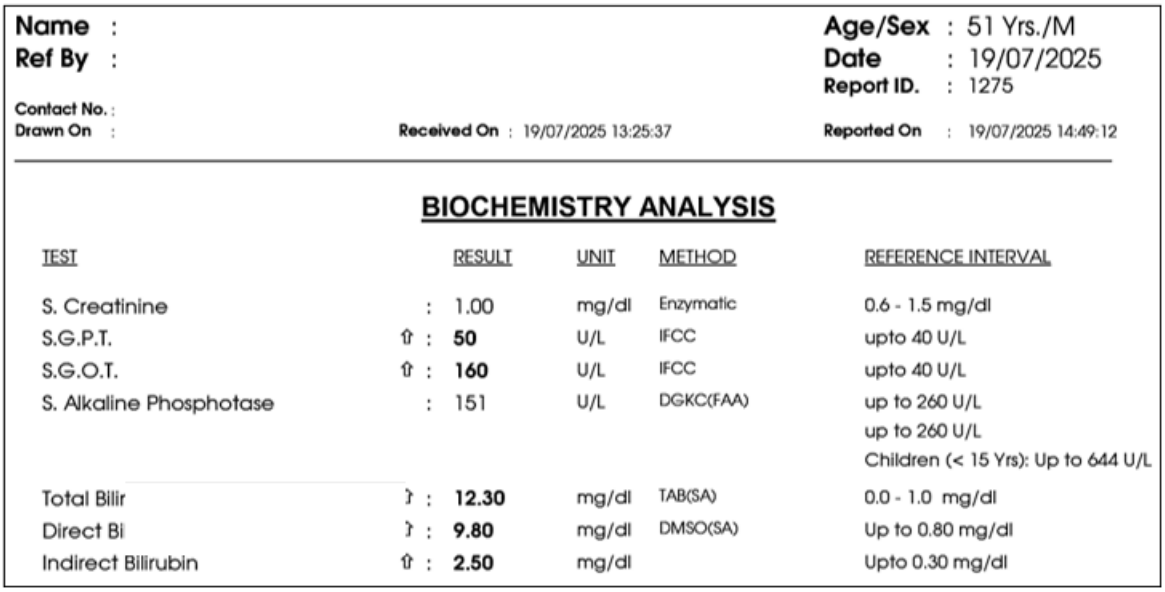
The therapeutic benefits in this case can be attributed to the paracrine signaling mechanisms mediated by MSCs and exosomes. Exosomes are rich in anti-inflammatory cytokines such as interleukin-10 (IL-10) and transforming growth factor-beta (TGF-β), which suppress immune-mediated injury within the liver and reduce the production of pro-fibrotic mediators. In addition, growth factors such as vascular endothelial growth factor (VEGF), hepatocyte growth factor (HGF), epidermal growth factor (EGF), and insulin-like growth factor-1 (IGF-1), which are secreted by MSCs and carried by exosomes, stimulate hepatocyte proliferation, angiogenesis, and tissue repair. These molecules also promote hepatocyte survival by upregulating anti-apoptotic genes while downregulating pro-apoptotic pathways.

Further, MSCs and exosomes exert antifibrotic effects by directly suppressing the activation of hepatic stellate cells and reducing deposition of extracellular matrix proteins, thereby contributing to regression of fibrosis. Exosomal microRNAs, such as miR-122 and miR-181, have been shown to regulate gene expression within hepatocytes and stellate cells, driving processes of regeneration and reducing scar formation [15,20,25]. The recruitment of macrophages and modulation of their phenotype from pro-inflammatory M1 to anti-inflammatory M2 subsets further facilitates the resolution of chronic inflammation in cirrhotic livers.

Taking together, this case adds to the growing body of evidence supporting the use of MSC- and exosome-based therapies as a promising regenerative strategy for patients with advanced liver cirrhosis. The observed reduction in bilirubin levels and symptomatic recovery highlights the clinical relevance of harnessing the MSC secretome in managing hepatic failure. While liver transplantation remains the gold standard, our findings indicate that MSC- and exosome-based interventions may provide a viable alternative or bridging therapy for patients who are ineligible or unwilling to undergo transplantation.

Table 1: Serial changes in bilirubin levels following IV MSC + exosome therapy

Time Point	Total Bilirubin (mg/dL)	Direct Bilirubin (mg/dL)	Indirect Bilirubin (mg/dL)
Baseline (Pre-treatment)	12.30	9.80	2.50
Week 2 of Treatment	6.50	4.87	1.63
1-Month Follow-up	4.60	3.50	1.10

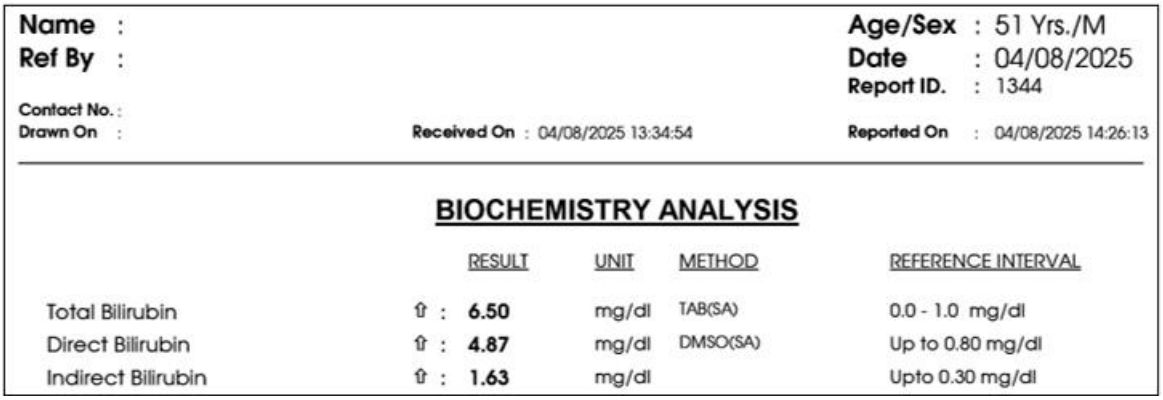


Name :
Ref By :
Contact No. :
Drawn On :
Age/Sex : 51 Yrs./M
Date : 19/07/2025
Report ID. : 1275
Received On : 19/07/2025 13:25:37
Reported On : 19/07/2025 14:49:12

BIOCHEMISTRY ANALYSIS

TEST		RESULT	UNIT	METHOD	REFERENCE INTERVAL
S. Creatinine	:	1.00	mg/dl	Enzymatic	0.6 - 1.5 mg/dl
S.G.P.T.	⇧ :	50	U/L	IFCC	upto 40 U/L
S.G.O.T.	⇧ :	160	U/L	IFCC	upto 40 U/L
S. Alkaline Phosphotase	:	151	U/L	DGKC(FAA)	up to 260 U/L up to 260 U/L Children (< 15 Yrs): Up to 644 U/L
Total Bilir	⇧ :	12.30	mg/dl	TAB(SA)	0.0 - 1.0 mg/dl
Direct Bi	⇧ :	9.80	mg/dl	DMSO(SA)	Up to 0.80 mg/dl
Indirect Bilirubin	⇧ :	2.50	mg/dl		Upto 0.30 mg/dl

1(A)

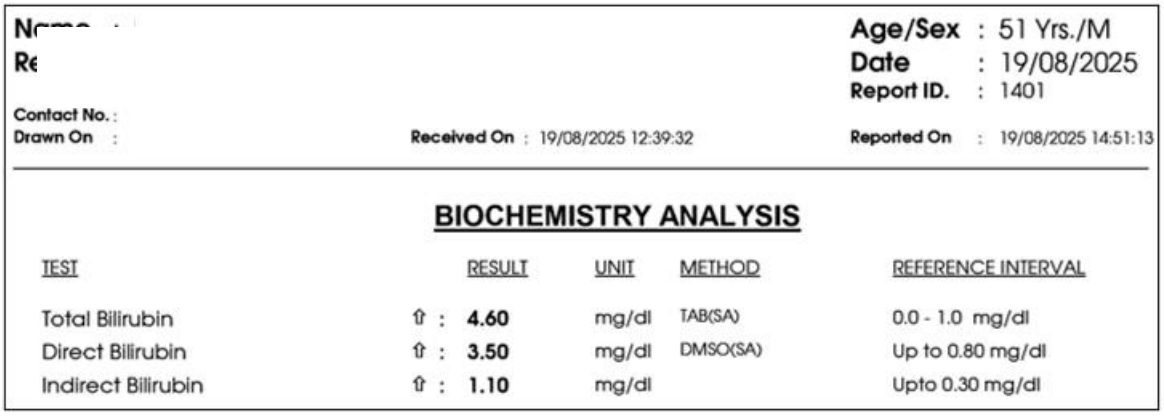


Name :
Ref By :
Contact No. :
Drawn On :
Age/Sex : 51 Yrs./M
Date : 04/08/2025
Report ID. : 1344
Received On : 04/08/2025 13:34:54
Reported On : 04/08/2025 14:26:13

BIOCHEMISTRY ANALYSIS

		RESULT	UNIT	METHOD	REFERENCE INTERVAL
Total Bilirubin	⇧ :	6.50	mg/dl	TAB(SA)	0.0 - 1.0 mg/dl
Direct Bilirubin	⇧ :	4.87	mg/dl	DMSO(SA)	Up to 0.80 mg/dl
Indirect Bilirubin	⇧ :	1.63	mg/dl		Upto 0.30 mg/dl

1(B)



Age/Sex : 51 Yrs./M
Date : 19/08/2025
Report ID. : 1401
Contact No. :
Drawn On :
Received On : 19/08/2025 12:39:32
Reported On : 19/08/2025 14:51:13

BIOCHEMISTRY ANALYSIS

TEST		RESULT	UNIT	METHOD	REFERENCE INTERVAL
Total Bilirubin	⇧ :	4.60	mg/dl	TAB(SA)	0.0 - 1.0 mg/dl
Direct Bilirubin	⇧ :	3.50	mg/dl	DMSO(SA)	Up to 0.80 mg/dl
Indirect Bilirubin	⇧ :	1.10	mg/dl		Upto 0.30 mg/dl

1(C)

Figure 1: Sequential pathology reports of the patient demonstrate a steady reduction in bilirubin levels following intravenous mesenchymal stem cell and exosome treatment. **1(A)** Report at admission showing significantly elevated bilirubin (12.30 mg/dL). **1(B)** Report after two weeks of therapy (second cycle), with bilirubin reduced to 6.50 mg/dL. **1(C)** Report at one month, following completion of treatment (third cycle), indicating further improvement with bilirubin decreasing to 4.60 mg/dL. For reasons of confidentiality, the patient's name and identifying details have been removed. However, complete records and documentation are available and can be provided to the editorial board or reviewers upon request.

4. Conclusion

In this case of advanced liver cirrhosis, intravenous administration of 200 million donor-derived adipose mesenchymal stem cells (MSCs) and 90 billion amniotic fluid–derived exosomes over the course of one month resulted in a steady and clinically meaningful decline in bilirubin levels, from 12.30 mg/dL at baseline to 6.50 mg/dL after the second cycle, and further down to 4.60 mg/dL following completion of therapy. Alongside biochemical improvements, the patient experienced better energy, reduced fatigue, and enhanced overall well-being, which together

contributed to an improved quality of life. These findings highlight the potential of MSCs and exosomes to promote liver regeneration, modulate inflammation, and serve as a safe and effective therapeutic alternative for patients with cirrhosis who otherwise face the prospect of liver transplantation.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Funding

The current study was supported by CELLSTAR – Celleste Stem cell Therapy and Research.

References

[1] Amer ME, El-Sayed SZ, El-Kheir WA, et al. Evaluation of patients with end-stage liver cell failure injected with bone marrow–derived hepatocyte-like cells. Eur J Gastroenterol Hepatol. 2011;23(10):936–941.

[2] Amer ME, et al. Clinical and laboratory evaluation of patients with end-stage liver cell failure injected with bone marrow-derived hepatocyte-like cells. *Eur J Gastroenterol Hepatol*. 2011;23(10):936–941.

[3] Asrani SK, Devarbhavi H, Eaton J, Kamath PS. Burden of liver diseases in the world. *Journal of Hepatology*. 2019;70(1):151-171.

[4] Bernal W, Jalan R, Quaglia A, Simpson K, Wendon J, Burroughs A. Acute-on-chronic liver failure. *The Lancet*. 2015;386(10003):1576-1587.

[5] Dominici M, Le Blanc K, Mueller I, et al. Minimal criteria for defining multipotent mesenchymal stromal cells. *Cytotherapy*. 2006;8(4):315-317.

[6] Friedman SL. Hepatic stellate cells: protean, multifunctional, and enigmatic cells of the liver. *Physiol Rev*. 2008;88(1):125-172.

[7] Kamath PS, Kim WR. The model for end-stage liver disease (MELD). Hepatology. 2007;45(3):797–805.

[8] Kharaziha P, Hellström PM, Noorinayer B, et al. Improvement of liver function in cirrhosis patients after autologous mesenchymal stem cell injection: A phase I–II clinical trial. Eur J Gastroenterol Hepatol. 2009;21(10):1199–1205.

[9] Kim WR, Lake JR, Smith JM, et al. OPTN/SRTR 2017 Annual Data Report: Liver. Am J Transplant. 2019;19(Suppl 2):184–283.

[10] Koyama Y, Brenner DA. Liver inflammation and fibrosis. *J Clin Invest*. 2017;127(1):55-64.

[11] Kuo TK, et al. Stem cell therapy for liver disease: parameters governing the success of hepatocyte differentiation. *Liver Transpl*. 2008;14(9):1332–1344.

[12] Li J, et al. Mesenchymal stem cell therapy for liver fibrosis: a preclinical and clinical update. *J Hepatol*. 2019;70(1):169–182.

[13] Li T, et al. Exosomes derived from human umbilical cord mesenchymal stem cells alleviate liver fibrosis. *Stem Cell Res Ther*. 2013;4(6):123.

[14] Lin BL, Chen JF, Qiu WH, et al. Allogeneic bone marrow-derived mesenchymal stromal cells for HBV-related acute-on-chronic liver failure: a randomized trial. Hepatology. 2017;66(1):209–219.

[15] Lou G, et al. Exosomes derived from mesenchymal stem cells regulate TLR4 signaling pathway in liver fibrosis. *Mol Immunol*. 2017; 82: 23–31.

[16] Mohamadnejad M, Alimoghaddam K, Bagheri M, et al. Randomized placebo-controlled trial of mesenchymal stem cell transplantation in decompensated cirrhosis. *Liver Int*. 2013;33(10):1490-1496.

[17] Mohamadnejad M, et al. Transplantation of mesenchymal stem cells in cirrhosis: a phase 1 trial. *Liver Int*. 2007;27(9):1274–1282.

[18] Mohamadnejad M, Namiri M, Bagheri M, et al. Phase 1 trial of autologous bone marrow mesenchymal stem cell transplantation in patients with decompensated liver cirrhosis. Arch Iran Med. 2007;10(4):459–466.

[19] Pellicoro A, Ramachandran P, Iredale JP, Fallowfield JA. Liver fibrosis and repair: immune regulation of wound healing in a solid organ. *Nat Rev Immunol*. 2014;14(3):181-194.

[20] Rong X, et al. Therapeutic effect of MSC-derived exosomes in liver cirrhosis. *Stem Cells Int*. 2020; 2020: 1–12.

[21] Schuppan D, Afdhal NH. Liver cirrhosis. Lancet. 2008;371(9615):838–851.

[22] Shi M, Liu Z, Wang Y, Xu R, Sun Y, Zhang M, Yu X, Wang H, Meng L, Su H, Jin L, Han Z, Han ZC. A pilot study of mesenchymal stem cell therapy for acute liver allograft rejection. *Stem Cells Transl Med*. 2017;6(12):2053-2061.

[23] Shi M, Liu ZW, Wang FS. Stem cell therapy for chronic liver diseases: Clinical progress and challenges. J Gastroenterol. 2014;49(2):185–194.

[24] Suk KT, et al. Transplantation with autologous bone marrow–derived mesenchymal stem cells for alcoholic cirrhosis: phase 2 clinical trial. *Hepatology*. 2016;64(6):2185–2197.

[25] Tan CY, et al. Mesenchymal stem cell-derived exosomes promote hepatic regeneration in liver failure. *Stem Cell Res Ther*. 2014;5(5):76.

[26] Tsochatzis EA, Bosch J, Burroughs AK. Liver cirrhosis. Lancet. 2014;383(9930):1749–1761.

[27] Vizoso FJ, Eiro N, Cid S, Schneider J, Perez-Fernandez R. Mesenchymal stem cell secretome: toward cell-free therapeutic strategies in regenerative medicine. *Int J Mol Sci*. 2017;18(9):1852.

[28] Wang Y, Yu X, Chen E, et al. Mesenchymal stem cells in liver fibrosis: New insights. Front Physiol. 2014; 5: 123.

[29] Zhao DC, et al. Bone marrow-derived mesenchymal stem cells protect against experimental liver fibrosis in rats. *World J Gastroenterol*. 2005;11(22):3431–3440.

[30] Zhao Z, Ma X, Ma J, Sun X, Li F, Lv J. Therapeutic effects of mesenchymal stem cells for patients with chronic liver diseases: an updated meta-analysis. *Stem Cells Int*. 2019; 2019: 5626181.