

# World Journal of *Transplantation*

*World J Transplant* 2023 June 18; 13(4): 107-207



**REVIEW**

- 107 Islet transplantation-immunological challenges and current perspectives

*Kabakchieva P, Assyov Y, Gerasoudis S, Vasilev G, Peshevska-Sekulovska M, Sekulovski M, Lazova S, Miteva DG, Gulinac M, Tomov L, Velikova T*

**MINIREVIEWS**

- 122 Intracranial pressure monitoring in the perioperative period of patients with acute liver failure undergoing orthotopic liver transplantation

*Mendoza Vasquez LE, Payne S, Zamper R*

- 129 Women's health issues in solid organ transplantation: Breast and gynecologic cancers in the post-transplant population

*Jones-Pauley M, Kodali S, Basra T, Victor DW*

**ORIGINAL ARTICLE****Retrospective Cohort Study**

- 138 Pre-Lung transplant reflux testing demonstrates high prevalence of gastroesophageal reflux in cystic fibrosis and reduces chronic rejection risk

*Lo WK, Flanagan R, Sharma N, Goldberg HJ, Chan WW*

**Retrospective Study**

- 147 Mortality assessment for pancreas transplants in the United States over the decade 2008-2018

*Jarmi T, Brennan E, Clendenon J, Spaulding AC*

- 157 Is peri-transplant blood transfusion associated with worse transplant outcomes? A retrospective study

*Bukhari MA, Alhomayani FK, Al Eid HS, Al-Malki NK, Alotaibi ME, Hussein MA, Habibullah ZN*

- 169 Delayed referral for liver transplant evaluation worsens outcomes in chronic liver disease patients requiring inpatient transplant evaluation

*Cooper KM, Colletta A, Hathaway NJ, Liu D, Gonzalez D, Talat A, Barry C, Krishnarao A, Mehta S, Movahedi B, Martins PN, Devuni D*

**Observational Study**

- 183 Haemodynamic management in brain death donors: Influence of aetiology of brain death

*Lazzeri C, Bonizzoli M, Batacchi S, Guetti C, Vessella W, Valletta A, Ottaviano A, Peris A*

- 190 Randomized intervention to assess the effectiveness of an educational video on organ donation intent among Hispanics in the New York metropolitan area

*Pekmezaris R, Cigaran E, Patel V, Clement D, Sardo Molmenti CL, Molmenti E*

**CASE REPORT**

- 201**    Efficacy and safety of local candida immunotherapy in recalcitrant warts in pediatric kidney transplantation: A case report

*Acharya R, Bush R, Johns F, Upadhyay K*

**ABOUT COVER**

Peer Reviewer of *World Journal of Transplantation*, Mendy Hatibie Oley, MD, PhD, Plastic Reconstructive and Aesthetic Surgery Division, General Surgery Department, Faculty of Medicine, Sam Ratulangi University, Kandou General Hospital, North Sulawesi 95115, Indonesia. mendy.hatibie@unsrat.ac.id

**AIMS AND SCOPE**

The primary aim of *World Journal of Transplantation* (WJT, *World J Transplant*) is to provide scholars and readers from various fields of transplantation with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJT mainly publishes articles reporting research results obtained in the field of transplantation and covering a wide range of topics including bone transplantation, brain tissue transplantation, corneal transplantation, descemet stripping endothelial keratoplasty, fetal tissue transplantation, heart transplantation, kidney transplantation, liver transplantation, lung transplantation, pancreas transplantation, skin transplantation, etc.

**INDEXING/ABSTRACTING**

The WJT is now abstracted and indexed in PubMed, PubMed Central, Scopus, Reference Citation Analysis, China National Knowledge Infrastructure, China Science and Technology Journal Database, and Superstar Journals Database.

**RESPONSIBLE EDITORS FOR THIS ISSUE**

**Production Editor:** Yan-Liang Zhang; **Production Department Director:** Xu Guo; **Editorial Office Director:** Jia-Ping Yan.

**NAME OF JOURNAL**

*World Journal of Transplantation*

**ISSN**

ISSN 2220-3230 (online)

**LAUNCH DATE**

December 24, 2011

**FREQUENCY**

Quarterly

**EDITORS-IN-CHIEF**

Maurizio Salvadori, Sami Akbulut, Vassilios Papalois, Atul C Mehta

**EDITORIAL BOARD MEMBERS**

<https://www.wjgnet.com/2220-3230/editorialboard.htm>

**PUBLICATION DATE**

June 18, 2023

**COPYRIGHT**

© 2023 Baishideng Publishing Group Inc

**INSTRUCTIONS TO AUTHORS**

<https://www.wjgnet.com/bpg/gerinfo/204>

**GUIDELINES FOR ETHICS DOCUMENTS**

<https://www.wjgnet.com/bpg/gerinfo/287>

**GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH**

<https://www.wjgnet.com/bpg/gerinfo/240>

**PUBLICATION ETHICS**

<https://www.wjgnet.com/bpg/gerinfo/288>

**PUBLICATION MISCONDUCT**

<https://www.wjgnet.com/bpg/gerinfo/208>

**ARTICLE PROCESSING CHARGE**

<https://www.wjgnet.com/bpg/gerinfo/242>

**STEPS FOR SUBMITTING MANUSCRIPTS**

<https://www.wjgnet.com/bpg/gerinfo/239>

**ONLINE SUBMISSION**

<https://www.f6publishing.com>



## Intracranial pressure monitoring in the perioperative period of patients with acute liver failure undergoing orthotopic liver transplantation

Luis Eduardo Mendoza Vasquez, Sonja Payne, Raffael Zamper

**Specialty type:** Transplantation

**Provenance and peer review:**

Invited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review report's scientific quality classification**

Grade A (Excellent): 0  
Grade B (Very good): B, B  
Grade C (Good): 0  
Grade D (Fair): 0  
Grade E (Poor): 0

**P-Reviewer:** Ferrarese A, Italy

**Received:** December 23, 2022

**Peer-review started:** December 23, 2022

**First decision:** March 15, 2023

**Revised:** March 28, 2023

**Accepted:** April 12, 2023

**Article in press:** April 12, 2023

**Published online:** June 18, 2023



**Luis Eduardo Mendoza Vasquez, Sonja Payne, Raffael Zamper**, Department of Anesthesia and Perioperative Medicine, London Health Science Centre, London N6A 5A5, Ontario, Canada

**Corresponding author:** Raffael Zamper, PhD, Assistant Professor, Department of Anesthesia and Perioperative Medicine, London Health Science Centre, 339 Windermere Road, London N6A 5A5, Ontario, Canada. [rzamper@me.com](mailto:rzamper@me.com)

### Abstract

Acute liver failure (ALF) may result in severe neurological complications caused by cerebral edema and elevated intracranial pressure (ICP). Multiple pathogenic mechanisms explain the elevated ICP, and newer hypotheses have been described. While invasive ICP monitoring (ICPM) may have a role in ALF management, these patients are typically coagulopathic and at risk for intracranial hemorrhage. ICPM is the subject of much debate, and significant heterogeneity exists in clinical practice regarding its use. Contemporary ICPM techniques and coagulopathy reversal strategies may be associated with a lower risk of hemorrhage; however, most of the evidence is limited by its retrospective nature and relatively small sample size.

**Key Words:** Acute liver failure; Liver transplant; Hepatic encephalopathy; Intracranial hypertension; Brain edema

©The Author(s) 2023. Published by Baishideng Publishing Group Inc. All rights reserved.

**Core Tip:** Despite its rare occurrence, acute liver failure generates academic interest from multiple disciplines because of its multiorgan involvement and high morbidity and mortality. Severe neurological complications may arise, requiring invasive monitoring with the potential risk of fatal intracranial bleeding. Newer strategies could decrease the risks while keeping the benefits.

**Citation:** Mendoza Vasquez LE, Payne S, Zamper R. Intracranial pressure monitoring in the perioperative period of patients with acute liver failure undergoing orthotopic liver transplantation. *World J Transplant* 2023; 13(4): 122-128

**URL:** <https://www.wjgnet.com/2220-3230/full/v13/i4/122.htm>

**DOI:** <https://dx.doi.org/10.5500/wjt.v13.i4.122>

## INTRODUCTION

### **Definition and incidence**

Acute liver failure (ALF) is a rare syndrome caused by abrupt hepatocyte injury that can progress to a fatal outcome in days to weeks. The most widely accepted definition of ALF includes evidence of coagulopathy and any degree of mental alteration (*i.e.*, encephalopathy) within 26 wk in a patient without preexisting liver disease[1]. Classification according to etiology highlights associated prognostic value and disease-specific treatment. An alternative classification quantifies the interval between symptom onset and development of encephalopathy; hyperacute (0–7 d), acute (8–28 d), and subacute (1–3 mo)[2]. The incidence of ALF in the United States of America is thought to be close to 3000 cases per year[3].

Despite its rare occurrence, ALF generates academic interest from multiple disciplines because of its multiorgan involvement and high morbidity and mortality. The survival from ALF has improved in recent years through better knowledge of pathophysiology, advances in critical care management, and access to emergency liver transplantation (LT)[4].

### **Etiology, pathophysiology and multiorgan involvement**

The pathophysiological process that leads to hepatocyte injury causes either direct toxic necrosis or immune apoptotic injury; the predominant cause for direct injury is acetaminophen toxicity, developing from hours to days[5]. The immune apoptotic injury is a slower injury process, led by hepatitis B infection/reactivation, autoimmune hepatitis, and drug-induced liver injury[6,7]. ALF is characterized by the development of hepatic encephalopathy (HE), and the loss of synthetic dysfunction in the form of coagulopathy. An elevated prothrombin time is a marker of synthetic dysfunction that occurs from the decrease in the vitamin K-dependent coagulation factors (II, VII, IX, X); prolongation of the INR more than 1.5 is considered a poor prognostic sign and a cornerstone of ALF diagnostic criteria.

The pathophysiology of ALF can be divided into primary liver injury specific to etiology and secondary multiorgan failure. The primary liver insult of acetaminophen-induced ALF has the best understood mechanism, namely glutathione depletion. The secondary multiorgan failure, severe systemic inflammation and microcirculatory alterations contribute to a clinical picture comparable to a distributive shock[8]. The vascular tone of the brain and kidneys are most vulnerable, leading to cerebral edema, encephalopathy, and functional renal failure[9].

## NEUROLOGICAL DYSFUNCTION IN ALF

The central place of HE in the definition of ALF reflects its key prognostic impact, and its development reflects severely impaired liver function. A multiaxial definition of the syndromes of HE was developed for chronic liver disease by the International Society for Hepatic Encephalopathy and Nitrogen Metabolism based on the type of underlying hepatic abnormality, the time course, and severity of neurological manifestations[10]. The American and European Associations for the Study of Liver Diseases practice guidelines highlights the distinct features of HE in ALF and the association of HE with increased intracranial pressure (ICP)[11].

Cerebral edema and resulting intracranial hypertension (ICH) are the most severe neurological clinical manifestations in patients with ALF. In the past, cerebral edema was presumed to occur in up to 80% of patients with ALF. However, recent data from developed countries estimates a drop in the incidence to 20%-30%, probably due to earlier diagnosis and improved management[12].

### **Pathogenesis of brain edema in ALF**

The pathogenesis of cerebral edema in ALF is complex and only partially understood, and its occurrence is related to the severity of encephalopathy. Cerebral edema is occasionally observed in patients with grade I-II encephalopathy; moreover, the risk of edema increases to 25% to 35% with progression to grade III, and 65% to 75% or more in patients reaching grade IV coma[13].

Potential contributing factors include cytotoxicity due to osmotic effects of ammonia, glutamine, and proinflammatory cytokines, vasogenic edema due to disruption of the blood-brain barrier with the rapid accumulation of low molecular substances, and the loss of the cerebral blood flow autoregulation.



Multiple studies support astrocyte swelling and cytotoxic edema as major contributors to cerebral edema in ALF[12,14,15]; the evidence is most compelling in the central role of ammonia causing astrocyte swelling. The ammonia-glutamine hypothesis has persisted over years, describing an excess of ammonia in the brain which is converted to glutamine with resulting osmotic effects on astrocytes. New studies have challenged this hypothesis, concluding that astrocyte swelling may not be the result of glutamine's direct osmotic effect; instead, a "Trojan horse" hypothesis is proposed in which glutamine may function as a carrier of ammonia into the mitochondria where its accumulation can lead to oxidative stress and ultimately cellular swelling[16]. Oxidative stress has been implicated as an important factor in the pathophysiology of ammonia-induced neurotoxicity through the formation of free radicals which may result in mitochondrial permeability transition[17].

Other studies have suggested that neuroinflammatory mediators, particularly proinflammatory cytokines such as the interleukins (IL)-1 $\beta$  and IL-6 and tumor necrosis factor- $\alpha$ , play an essential role in the development of brain edema and ICH[18,19]. Neuroinflammation is now widely considered the result of a direct interaction between microglia and ammonia. The released proinflammatory cytokines from activated microglia cells and ammonia appear to act synergistically to induce cytotoxic cerebral edema in which the blood-brain barrier is preserved.

Research combining brain imaging in the context of ALF demonstrates evidence of interstitial brain edema in addition to cytotoxic brain edema, implying the presence of vasogenic edema, in which the blood-brain barrier would be compromised[20,21]. Although a generalized breakdown of the blood-brain barrier cannot be demonstrated, some studies propose the "leaky" theory, in which there are subtle changes in the integrity of the tight junctions of the blood-brain barrier. The exact mechanism of how cytotoxic, vasogenic, and neuroinflammation interact to bring brain edema in ALF remains unknown.

### ***The role of ICP monitoring in ALF***

The Brain Trauma Foundation guidelines explicitly recommend ICP monitoring (ICPM) for patients with severe traumatic brain injury to minimize mortality[22]; however, recommendations for ICPM in patients with non-traumatic brain injury are lacking. The rationale for using monitors to measure the pressure inside the cranium in ALF considers the potential benefit of early identification and management of ICH. In addition, continuous ICP measurements contribute to the decision-making process for emergency LT; intraoperative ICPM facilitates active neurological management in the setting of rapid fluid shifts and hemodynamic instability.

Invasive ICPM remains the gold standard for the measurement of ICP[23], which may reveal occult elevations in ICP in comatose patients with ALF[24]. Despite the proposed benefits, invasive ICPM in this unique patient population raises concern due to the risk of life-threatening intracranial hemorrhage in the setting of coagulopathy.

Noninvasive ICPMs offer an alternative solution in this specific group of patients, employing techniques of optic nerve ultrasound and transcranial doppler. However, current evidence does not support its use to accurately identify patients with ICH. One study evaluated noninvasive ICPM techniques in comparison to the gold standard of invasive ICPM; the authors concluded that neither optic nerve ultrasound nor transcranial doppler pulsatility index correlated with the gold standard[25]. Another standard noninvasive option is cerebral computerized tomography, yet, evidence demonstrates this method's failure to consistently detect brain edema in patients with elevated ICP[23]. In addition, the complexity of intrahospital transport for critically ill patients should not be underestimated.

With invasive ICPMs identified as the most accurate modality to identify ICH in patients with ALF, several invasive options exist. Transducers may be placed in the brain parenchyma, ventricular system, epidural or subdural spaces. Epidural devices have lower complication rates than subdural or intraparenchymal monitors[26]. A ventricular system has the potential to be diagnostic and therapeutic as cerebrovascular fluid can be drained; however, intraventricular placement may be associated with severe and potentially fatal hemorrhage.

### ***LT in ALF***

With high-grade HE identified as an independent predictor of mortality in patients with ALF, LT is a potentially life-saving intervention[27]. Access to emergency LT has improved survival rates for patients that fulfill criteria for a poor prognosis. The King's College Criteria remains the most clinically useful prediction tool, with disease-specific modeling for paracetamol and non-paracetamol categories[28]. Post-LT outcomes in this population are high with one- and three-year patient survival rates reported as 91% and 90% respectively[28].

### ***Consensus guidelines for ICP monitor use***

A review of the current literature highlights the lack of consensus regarding the use of ICPM in patients with ALF. The Acute Liver Failure Study Group guidelines does not recommend the use of external ventricular devices to monitor ICP for all patients with ALF; however, they recognize that most centers will place ICPM in patients with advanced encephalopathy[29,30]. A survey of 24 centers in the United States of America demonstrated that a minority (approximately 30%) of centers utilized ICPM[31].

Invasive ICPM use in Europe is more prevalent with 55% of centers surveyed reporting use of this monitoring modality[26]. In both surveys, invasive ICPM was reserved for patients with advanced encephalopathy according to The West Haven criteria; the type of invasive monitor use was not specified. The American Association for the Study of the Liver recommends invasive ICPM in patients with ALF awaiting LT and in centers with expertise[28]; The European Association for the Study of the Liver recommends monitoring only in a select group of patients including those with advanced encephalopathy at risk of ICH, hyperammonemia, and renal or vasopressor support[32]. Table 1 summarizes the current large-society recommendations.

Robust data regarding the impact on long-term neurological consequences of cerebral edema and ICH in patients with ALF is scarce. Similarly, evidence reporting outcomes associated with the use of ICPM in this patient population is also lacking. Karvellas *et al*[33] reported a multicenter retrospective cohort study involving 140 patients managed with ICPM *vs* 489 controls without ICPM; the mortality at 21 d was not significantly different[33].

### ***The incidence of spontaneous intracranial hemorrhage in ALF***

The estimated risk of spontaneous intracranial hemorrhage in overt encephalopathy grade III and IV is 25%-35% and 65%-75% respectively[34]. The incidence of intracranial hemorrhage has decreased over many years. Bernal *et al*[4] reported a series of 3300 patients, in which intracranial hemorrhage occurred in more than 70% of patients on initial analysis with a dramatic reduction in incidence to only 20%, with a corresponding reduction in mortality, 20 years later[4]. The same author reported 29% incidence of intracranial hemorrhage in a series of more than 160 patients with overt encephalopathy[14]. The risk factors for intracranial hemorrhage include hyperacute presentation, younger age, and requirements of vasopressors or renal replacement therapy[14,35].

### ***Risk of bleeding and outcomes from the use of invasive ICPM in ALF***

The general incidence of hemorrhagic complications from ICPM is approximately 10%-20% with fatal hemorrhage reported in 1%-5% of patients[31,36]. The risk of intracranial bleeding is related to the type of device and location of the ICPM placement. Some authors claim a reduction in bleeding risk by a meticulous insertion technique and targeted peri-procedural transfusion (*e.g.*, recombinant factor VIIa prior to the placement of the ICPM)[37]. A literature search from 1992 to 2017 shows eleven studies reporting the use of ICPM in ALF; only four of these studies described an institutional protocol to correct the coagulopathy prior to the insertion of ICPM. Variable use of peri-procedural blood product transfusion was observed.

Another potential complication associated with ICPM insertion is infection. The general risk of infection is approximately 1%-20%[38]. To our knowledge, ALF patients have no associated increase in infection risk; however, data is limited. Multiple small case series demonstrated a low incidence of ICPM-related infections[24,37,39]. Reported rates of infection ranged from 0%-7%. A common practice to reduce infection risk is the administration of prophylactic intravenous antibiotics to cover the typical skin flora prior to ICPM placement.

---

## **TECHNICAL ASPECTS FOR ICPM**

---

It is important to acknowledge that regardless of the transducer selected, the management of ICP should be guided by the cerebral perfusion pressure. The cerebral perfusion is estimated by the difference between the mean cerebral arterial pressure and the ICP. To ensure accurate measurement of cerebral arterial pressure, it is recommended that the arterial line transducer should be positioned at the external auditory meatus, level with the middle cranial fossa[40].

Interventions for managing brain edema and ICH in ALF are out of the scope of this article. However, standard measures are to maintain adequate sedation, head elevation at 30 degrees, target plasma sodium levels of 145 to 155 mEq/L, maintain normocapnia with a CO<sub>2</sub> of 35 mmHg, a plasma osmolality of 320 mOsm/L, a mean arterial blood pressure of 75-80 mmHg, and temperature between 32-34 °C for 10-14 h in candidates for LT[41].

---

## **SINGLE-CENTER EXPERIENCE**

---

Using the limited evidence and large-society guidelines, a protocol was developed and implemented to guide management of severe neurological consequences of ALF in our center. Integral to this document is the recommendation for the use of invasive ICPM in carefully selected patients. Protocol development engaged representatives from all multidisciplinary stakeholders including hepatology, anesthesia, critical care, and surgery. Explicit clinical criteria outlined patients appropriate for invasive ICPM use.

As outlined in this protocol, patients with high-grade HE (grade III and IV) in the context of ALF, with the possibility of recovery from medical intervention and/or LT, warrant ICPM insertion.



**Table 1 Summary of recommendations for intracranial pressure monitor in patients with acute liver failure**

Society	Recommendation	Quality of evidence
AASLD 2005[1]	ICPM is mainly considered for patients who are listed for transplantation. In the absence of ICPM, frequent evaluation for signs of intracranial hypertension is needed to identify early evidence of uncal herniation	Evidence level III
AASLD Revised 2011[28]	The use of recombinant factor rVIIa may be considered	NA
ALSFG 2007[30]	Insufficient data to recommend ICPM placement in all patients with ALF. However, most members of the ALSFG place ICPM in patients with advanced (stage III/IV) hepatic encephalopathy	NA
EASL 2017 [32]	ICPM should be considered in a highly selected subgroup of patients, who have progressed to grade 3 or 4 coma, are intubated and ventilated and deemed at high risk of intracranial hemorrhage, based on the presence of more than one of the following variables: (1) Young patients with hyperacute or acute presentations; (2) ammonia level over 150–200 $\mu\text{mol/L}$ that does not drop with initial treatment interventions (RRT and fluids); (3) renal impairment; and (4) vasopressor support ( $> 0.1 \text{ kg/min}$ )	(Evidence level II-3, grade of Recommendation 1)

AASLD: American Association for the Study of Liver Diseases; ALSFG: United States Acute Liver Failure Study Group; EASL: European Association for the study of the Liver; ICPM: Intracranial pressure monitor; RRT: Renal replacement therapy; ALF: Acute liver failure; rVIIa: Recombinant factor VIIa; NA: Not available.

Due to the risk of severe brain edema, eventually obliterating the ventricles, our neurosurgical team is reluctant to use external ventricular devices, in addition to the increased risk of periprocedural hemorrhage. In our protocol, we use the Codman Microsensor™ intraparenchymal monitor, which measures ICP *via* a strain gauge microchip at the catheter's tip. Pressure is reflected as an electrical voltage transmitted to the proximal end of the catheter through nylon-encapsulated copper wires. The proximal end of the catheter is connected to the Codman Express™ monitor, which displays the ICP value. Following baseline brain imaging and before insertion, the ICPM is zeroed at atmospheric pressure; after insertion, opening pressure is determined, and real-time display and longitudinal recordings are obtained.

To minimize the risk of ICPM-associated hemorrhage, coagulation correction is frequently undertaken prior to device insertion. It is generally accepted that conventional coagulation tests (*e.g.*, INR and platelet count) provide a limited perspective of *in vivo* clot formation in patients with liver disease. With the growing popularity of viscoelastic testing (VET) to guide coagulation management during LT, VET has been proposed as a more comprehensive tool to facilitate invasive procedures such as ICPM insertion. Our protocol utilizes a combined approach of VET and conventional laboratory testing. In our early institutional experience, directed administration of recombinant factor VIIa, fibrinogen, platelets, and desmopressin has enabled intraparenchymal monitor insertion, maintenance, and removal without hemorrhagic complications.

## CONCLUSION

Future prospective studies are necessary to address the existing gaps in knowledge outlined in this review. Given the rarity of ALF, and the broad spectrum of presentation, it is unlikely that single-center studies will provide robust evidence. Most of the protocols currently in place, including the one used in our center, are derived from retrospective observational and expert consensus statements. It is paramount to define the specific population of patients in which insertion of ICPMs changes outcomes and standardized transfusion protocols to minimize the associated risk of bleeding.

## FOOTNOTES

**Author contributions:** All authors contribute to the review of literature, first author Mendoza Vasquez LE wrote the initial manuscript that was extensively reviewed and changed by the other two authors.

**Conflict-of-interest statement:** All the authors report no relevant conflicts of interest for this article.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <https://creativecommons.org/licenses/by-nc/4.0/>

**Country/Territory of origin:** Canada

**ORCID number:** Raffael Zamper [0000-0003-2783-3072](https://orcid.org/0000-0003-2783-3072).

**S-Editor:** Fan JR

**L-Editor:** A

**P-Editor:** Zhang YL

## REFERENCES

- 1 **Polson J**, Lee WM; American Association for the Study of Liver Disease. AASLD position paper: the management of acute liver failure. *Hepatology* 2005; **41**: 1179-1197 [PMID: [15841455](#) DOI: [10.1002/hep.20703](#)]
- 2 **O'Grady JG**, Schalm SW, Williams R. Acute liver failure: redefining the syndromes. *Lancet* 1993; **342**: 273-275 [PMID: [8101303](#) DOI: [10.1016/0140-6736\(93\)91818-7](#)]
- 3 **Wijdicks EFM**. Hepatic Encephalopathy. *N Engl J Med* 2017; **376**: 186 [PMID: [28076712](#) DOI: [10.1056/NEJMc1614962](#)]
- 4 **Bernal W**, Hyrylainen A, Gera A, Audimoolam VK, McPhail MJ, Auzinger G, Rela M, Heaton N, O'Grady JG, Wendon J, Williams R. Lessons from look-back in acute liver failure? *J Hepatol* 2013; **59**: 74-80 [PMID: [23439263](#) DOI: [10.1016/j.jhep.2013.02.010](#)]
- 5 **Bailey B**, Amre DK, Gaudreault P. Fulminant hepatic failure secondary to acetaminophen poisoning: a systematic review and meta-analysis of prognostic criteria determining the need for liver transplantation. *Crit Care Med* 2003; **31**: 299-305 [PMID: [12545033](#) DOI: [10.1097/00003246-200301000-00048](#)]
- 6 **Jayakumar S**, Chowdhury R, Ye C, Karvellas CJ. Fulminant viral hepatitis. *Crit Care Clin* 2013; **29**: 677-697 [PMID: [23830658](#) DOI: [10.1016/j.ccc.2013.03.013](#)]
- 7 **Wang K**. Molecular mechanisms of hepatic apoptosis. *Cell Death Dis* 2014; **5**: e996 [PMID: [24434519](#) DOI: [10.1038/cddis.2013.499](#)]
- 8 **Zoubek ME**, Lucena MI, Andrade RJ, Stephens C. Systematic review: ibuprofen-induced liver injury. *Aliment Pharmacol Ther* 2020; **51**: 603-611 [PMID: [31984540](#) DOI: [10.1111/apt.15645](#)]
- 9 **Dong V**, Nanchal R, Karvellas CJ. Pathophysiology of Acute Liver Failure. *Nutr Clin Pract* 2020; **35**: 24-29 [PMID: [31840297](#) DOI: [10.1002/ncp.10459](#)]
- 10 **Munk Lauridsen M**, Vilstrup H. Diagnosing covert hepatic encephalopathy. *Clin Liver Dis (Hoboken)* 2015; **5**: 71-74 [PMID: [31040954](#) DOI: [10.1002/cld.451](#)]
- 11 **Vilstrup H**, Amodio P, Bajaj J, Cordoba J, Ferenci P, Mullen KD, Weissenborn K, Wong P. Hepatic encephalopathy in chronic liver disease: 2014 Practice Guideline by the American Association for the Study of Liver Diseases and the European Association for the Study of the Liver. *Hepatology* 2014; **60**: 715-735 [PMID: [25042402](#) DOI: [10.1002/hep.27210](#)]
- 12 **Scott TR**, Kronsten VT, Hughes RD, Shawcross DL. Pathophysiology of cerebral oedema in acute liver failure. *World J Gastroenterol* 2013; **19**: 9240-9255 [PMID: [24409052](#) DOI: [10.3748/wjg.v19.i48.9240](#)]
- 13 **Muñoz SJ**. Difficult management problems in fulminant hepatic failure. *Semin Liver Dis* 1993; **13**: 395-413 [PMID: [8303321](#) DOI: [10.1055/s-2007-1007368](#)]
- 14 **Bernal W**, Hall C, Karvellas CJ, Auzinger G, Sizer E, Wendon J. Arterial ammonia and clinical risk factors for encephalopathy and intracranial hypertension in acute liver failure. *Hepatology* 2007; **46**: 1844-1852 [PMID: [17685471](#) DOI: [10.1002/hep.21838](#)]
- 15 **Vaquero J**, Chung C, Blei AT. Brain edema in acute liver failure. A window to the pathogenesis of hepatic encephalopathy. *Ann Hepatol* 2003; **2**: 12-22 [PMID: [15094701](#)]
- 16 **Albrecht J**, Norenberg MD. Glutamine: a Trojan horse in ammonia neurotoxicity. *Hepatology* 2006; **44**: 788-794 [PMID: [17006913](#) DOI: [10.1002/hep.21357](#)]
- 17 **Schliess F**, Görg B, Häussinger D. Pathogenetic interplay between osmotic and oxidative stress: the hepatic encephalopathy paradigm. *Biol Chem* 2006; **387**: 1363-1370 [PMID: [17081108](#) DOI: [10.1515/BC.2006.171](#)]
- 18 **Rodrigo R**, Cauli O, Gomez-Pinedo U, Agusti A, Hernandez-Rabaza V, Garcia-Verdugo JM, Felipe V. Hyperammonemia induces neuroinflammation that contributes to cognitive impairment in rats with hepatic encephalopathy. *Gastroenterology* 2010; **139**: 675-684 [PMID: [20303348](#) DOI: [10.1053/j.gastro.2010.03.040](#)]
- 19 **Zemtsova I**, Görg B, Keitel V, Bidmon HJ, Schrör K, Häussinger D. Microglia activation in hepatic encephalopathy in rats and humans. *Hepatology* 2011; **54**: 204-215 [PMID: [21452284](#) DOI: [10.1002/hep.24326](#)]
- 20 **Rai V**, Nath K, Saraswat VA, Purwar A, Rathore RK, Gupta RK. Measurement of cytotoxic and interstitial components of cerebral edema in acute hepatic failure by diffusion tensor imaging. *J Magn Reson Imaging* 2008; **28**: 334-341 [PMID: [18626948](#) DOI: [10.1002/jmri.21438](#)]
- 21 **Kale RA**, Gupta RK, Saraswat VA, Hasan KM, Trivedi R, Mishra AM, Ranjan P, Pandey CM, Narayana PA. Demonstration of interstitial cerebral edema with diffusion tensor MR imaging in type C hepatic encephalopathy. *Hepatology* 2006; **43**: 698-706 [PMID: [16557540](#) DOI: [10.1002/hep.21114](#)]
- 22 **Kolias AG**, Rubiano AM, Figaji A, Servadei F, Hutchinson PJ. Traumatic brain injury: global collaboration for a global challenge. *Lancet Neurol* 2019; **18**: 136-137 [PMID: [30663604](#) DOI: [10.1016/S1474-4422\(18\)30494-0](#)]
- 23 **Raghavan M**, Marik PE. Therapy of intracranial hypertension in patients with fulminant hepatic failure. *Neurocrit Care* 2006; **4**: 179-189 [PMID: [16627910](#) DOI: [10.1385/NCC.4.2.179](#)]
- 24 **Rajajee V**, Fontana RJ, Courey AJ, Patil PG. Protocol based invasive intracranial pressure monitoring in acute liver failure: feasibility, safety and impact on management. *Crit Care* 2017; **21**: 178 [PMID: [28693567](#) DOI: [10.1186/s13054-017-1788-7](#)]

- 10.1186/s13054-017-1762-6]
- 25 **Rajajee V**, Williamson CA, Fontana RJ, Courey AJ, Patil PG. Noninvasive Intracranial Pressure Assessment in Acute Liver Failure. *Neurocrit Care* 2018; **29**: 280-290 [PMID: 29948998 DOI: 10.1007/s12028-018-0540-x]
  - 26 **Rabinowich L**, Wendon J, Bernal W, Shibolet O. Clinical management of acute liver failure: Results of an international multi-center survey. *World J Gastroenterol* 2016; **22**: 7595-7603 [PMID: 27672280 DOI: 10.3748/wjg.v22.i33.7595]
  - 27 **Karvellas CJ**, Leventhal TM, Rakela JL, Zhang J, Durkalski V, Reddy KR, Fontana RJ, Stravitz RT, Lake JR, Lee WM, Parekh JR. Outcomes of patients with acute liver failure listed for liver transplantation: A multicenter prospective cohort analysis. *Liver Transpl* 2023; **29**: 318-330 [PMID: 35980605 DOI: 10.1002/lt.26563]
  - 28 **Lee WM**, Stravitz RT, Larson AM. Introduction to the revised American Association for the Study of Liver Diseases Position Paper on acute liver failure 2011. *Hepatology* 2012; **55**: 965-967 [PMID: 22213561 DOI: 10.1002/hep.25551]
  - 29 **Keays RT**, Alexander GJ, Williams R. The safety and value of extradural intracranial pressure monitors in fulminant hepatic failure. *J Hepatol* 1993; **18**: 205-209 [PMID: 8409336 DOI: 10.1016/s0168-8278(05)80247-8]
  - 30 **Stravitz RT**, Kramer AH, Davern T, Shaikh AO, Caldwell SH, Mehta RL, Blei AT, Fontana RJ, McGuire BM, Rossaro L, Smith AD, Lee WM; Acute Liver Failure Study Group. Intensive care of patients with acute liver failure: recommendations of the U.S. Acute Liver Failure Study Group. *Crit Care Med* 2007; **35**: 2498-2508 [PMID: 17901832 DOI: 10.1097/01.CCM.0000287592.94554.5F]
  - 31 **Vaquero J**, Fontana RJ, Larson AM, Bass NM, Davern TJ, Shakil AO, Han S, Harrison ME, Stravitz TR, Muñoz S, Brown R, Lee WM, Blei AT. Complications and use of intracranial pressure monitoring in patients with acute liver failure and severe encephalopathy. *Liver Transpl* 2005; **11**: 1581-1589 [PMID: 16315300 DOI: 10.1002/Lt.20625]
  - 32 **European Association for the Study of the Liver**; Clinical practice guidelines panel, Wendon, J; Panel members, Cordoba J, Dhawan A, Larsen FS, Manns M, Samuel D, Simpson KJ, Yaron I; EASL Governing Board representative, Bernardi M. EASL Clinical Practical Guidelines on the management of acute (fulminant) liver failure. *J Hepatol* 2017; **66**: 1047-1081 [PMID: 28417882 DOI: 10.1016/j.jhep.2016.12.003]
  - 33 **Karvellas CJ**, Fix OK, Battenhouse H, Durkalski V, Sanders C, Lee WM; U S Acute Liver Failure Study Group. Outcomes and complications of intracranial pressure monitoring in acute liver failure: a retrospective cohort study. *Crit Care Med* 2014; **42**: 1157-1167 [PMID: 24351370 DOI: 10.1097/CCM.0000000000000144]
  - 34 **Jalan R**. Intracranial hypertension in acute liver failure: pathophysiological basis of rational management. *Semin Liver Dis* 2003; **23**: 271-282 [PMID: 14523680 DOI: 10.1055/s-2003-42645]
  - 35 **Raschke RA**, Curry SC, Rempe S, Gerkin R, Little E, Manch R, Wong M, Ramos A, Leibowitz AI. Results of a protocol for the management of patients with fulminant liver failure. *Crit Care Med* 2008; **36**: 2244-2248 [PMID: 18664779 DOI: 10.1097/CCM.0b013e31818029a3]
  - 36 **Blei AT**, Olafsson S, Webster S, Levy R. Complications of intracranial pressure monitoring in fulminant hepatic failure. *Lancet* 1993; **341**: 157-158 [PMID: 8093756 DOI: 10.1016/0140-6736(93)90016-a]
  - 37 **Jinadasa SP**, Ruan QZ, Bayoumi AB, Sharma SV, Boone MD, Malik R, Chen CC, Kasper EM. Hemorrhagic Complications of Invasive Intracranial Pressure Monitor Placement in Acute Liver Failure: Outcomes of a Single-Center Protocol and Comprehensive Literature Review. *Neurocrit Care* 2021; **35**: 87-102 [PMID: 33205356 DOI: 10.1007/s12028-020-01143-7]
  - 38 **Nag DS**, Sahu S, Swain A, Kant S. Intracranial pressure monitoring: Gold standard and recent innovations. *World J Clin Cases* 2019; **7**: 1535-1553 [PMID: 31367614 DOI: 10.12998/wjcc.v7.i13.1535]
  - 39 **Maloney PR**, Mallory GW, Atkinson JL, Wijidicks EF, Rabinstein AA, Van Gompel JJ. Intracranial Pressure Monitoring in Acute Liver Failure: Institutional Case Series. *Neurocrit Care* 2016; **25**: 86-93 [PMID: 26966022 DOI: 10.1007/s12028-016-0261-y]
  - 40 **Thomas E**; NACCS, Czosnyka M, Hutchinson P; SBNS. Calculation of cerebral perfusion pressure in the management of traumatic brain injury: joint position statement by the councils of the Neuroanaesthesia and Critical Care Society of Great Britain and Ireland (NACCS) and the Society of British Neurological Surgeons (SBNS). *Br J Anaesth* 2015; **115**: 487-488 [PMID: 26187435 DOI: 10.1093/bja/aev233]
  - 41 **Gasco J**, Rangel-Castilla L, Franklin B, Thomas PG, Patterson JT. State-of-the-art management and monitoring of brain edema and intracranial hypertension in fulminant hepatic failure. A proposed algorithm. *Acta Neurochir Suppl* 2010; **106**: 311-314 [PMID: 19812970 DOI: 10.1007/978-3-211-98811-4\_58]



Published by **Baishideng Publishing Group Inc**  
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA

**Telephone:** +1-925-3991568

**E-mail:** [bpgoffice@wjgnet.com](mailto:bpgoffice@wjgnet.com)

**Help Desk:** <https://www.f6publishing.com/helpdesk>

<https://www.wjgnet.com>

