Clinical Features, Diagnosis, and Natural History of Drug-Induced Liver Injury

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Abstract

Patients with idiosyncratic drug-induced liver injury (DILI) can pose substantial diagnostic, prognostic, and therapeutic challenges to the practicing gastroenterologist. The presentation of DILI may vary from asymptomatic liver enzyme elevation to acute liver failure. Although most DILI resolves following drug discontinuation, up to 20% of patients progress to chronic DILI further challenging the clinicians diagnostic and management skills. Also, some medications can lead to advanced fibrosis, encephalopathy, and portal hypertension without significant elevation in liver enzymes during exposure. Finally, there are no objective tests to definitively diagnose DILI. Although causality assessment instruments are available, none are widely accepted or used in clinical practice. Therefore, the diagnosis of DILI depends on thorough and accurate history taking, follow-up of the patient’s clinical course and excluding more common causes of liver injury. In this review, we discuss the variable clinical presentations, course, and diagnostic methods used to establish a diagnosis and prognosis in DILI.

Keywords
► hepatotoxicity
► diagnostic tools
► prognosis
► histology
► acute
► chronic

There are increasing reports of drug-induced liver injury (DILI) leading to clinically significant acute and chronic liver disease in both children and adults.1–4 Drug-induced liver injury remains the leading cause of acute liver failure (ALF) in Western countries and the most common reason for removal of approved medications from the marketplace.5,6 The lack of objective diagnostic tests, wide range of clinical presentations and idiosyncratic nature of most cases (i.e., independent of drug dose, duration, route of exposure or identifiable host factors), makes DILI a significant challenge for the practicing gastroenterologist. In the last several years, data acquired from several ongoing prospective registries of DILI cases have started to shed more light on the clinical features, diagnosis, and clinical course of DILI.

Symptoms and Signs of Drug-Induced Liver Injury

The initial symptoms and signs of DILI are often nonspecific (e.g., fatigue, nausea, and abdominal pain). In the U.S. Drug Induced Liver Injury Network (DILIN) registry of over 1,200 consecutive cases, nausea was present in 60% and abdominal pain in 42% (Robert Fontana, personal communication). The onset of clinical symptoms can be important in determining the latency of a possible DILI episode. Liver-specific symptoms and signs (e.g., pruritus, jaundice, ascites, and encephalopathy) are usually only present in patients with more severe DILI. In the DILIN and Spanish registries, ~70% of patients were jaundiced at presentation and 51% had pruritus. Jaundice in the setting of an acute hepatocellular injury, is associated with a mortality of 10%, often referred to as Hy’s Law after the late Hy Zimmerman.1,2,7,8 Ascites and encephalopathy are well-known ominous signs of hepatic failure.9 Drug-induced liver injury remains the overall leading cause of acute liver failure (ALF) in the U.S. and idiosyncratic DILI is the second leading cause among cases where an etiology is identified.10 The leading agents causing ALF are antituberculosis agents (isoniazid), antiepileptics (phenytoin, valproate), and antibiotics (ketocnazole, nitrofurantoin), followed by herbal and dietary supplements (HDS).10,11
Drugs and HDS products may also cause subclinical liver injury. For example, isoniazid therapy for latent TB will cause mild serumalanine aminotransferase (ALT) elevation in up to 20% to 30% of treated patients. Many of these will develop tolerance and experience a decline in ALT levels despite continued INH use.12-14 The heparin compounds can cause asymptomatic serum ALT elevations as well. A recent study in healthy volunteers showed that most will have some elevation in serum ALT levels and many had elevations greater than 3 to 5 times the upper limit of normal.15 These elevations occur with all the heparin compounds even when delivered subcutaneously and resolve with continued therapy.16 The combination of human immunodeficiency virus (HIV) anti-retrovirals, atazanavir, and ritonavir can also cause self-limited unconjugated hyperbilirubinemia in up to 44% of treated patients that resolves with drug discontinuation.17

Immunoallergic features may be a prominent feature in some DILI patients and at least one immunologic feature was present in 23% of the DILLN patients.2 Certain agents such as allopurinol, sulfamethoxazole/trimetoprim, vancomycin, and phenytoin18-21 frequently present with prominent immunoallergic features such as rash, fever, serositis, eosinophilia, bone marrow suppression, and multiorgan involvement (DRESS). In general, rechallenge in such cases will lead to a more rapid recurrence presumably due to immunologic memory of T and B cells. Other medications such as nitrofurantoin, minocycline, and azathioprine show an association with immune-mediated injury that is indistinguishable from sporadic autoimmune hepatitis. Autoimmune markers (antinuclear and antismooth muscle antibodies) may be markedly positive and histology may look identical to autoimmune hepatitis. The latencies can be quite long (months to years) and confidently distinguishing DILI from autoimmune hepatitis (AIH) often depends on resolution with medication discontinuance and lack of need for prolonged immunosuppressive therapy.22 Biologics including anti-TNF agents used to treat inflammatory bowel disease can also lead to severe acute liver injury with autoimmune hepatitis-like features.23

**Atypical Clinical Presentations**

Drug-induced liver injury can occasionally present with only modest or no elevations in liver biochemistries. Chronic use of methotrexate is probably the most well-known example. Serum aminotransaminase elevations are typically mild, yet a steatotic liver injury with fibrosis can occur over months to years of therapy.24 The risk of cirrhosis was probably exaggerated in early reports due to confounding from concomitant alcohol consumption as well as underlying nonalcoholic fatty liver disease. Nevertheless, the potential for chronic liver injury in up to 5% to 10% of treated patients is widely accepted and guidelines from both dermatology25 and rheumatology26,27 professional societies recommend monitoring of serum aminotransferase levels with periodic liver biopsy depending on the levels, patient risk factors, and cumulative drug exposure.

Hepatotoxicity from the antiepileptic, valproate is noteworthy for its three distinct presentations (►Table 1).28,29 It may present acutely with jaundice, anorexia, and encephalopathy. Oddly, liver enzyme elevations may be modest in comparison to other injuries presenting with such severe hepatic dysfunction. Valproate hepatotoxicity can also present abruptly with a Reye’s-like syndrome typically in children. Here again, liver biochemistry abnormalities are often modest and overshadowed by the neurologic complaints of anorexia, lethargy, cerebral edema, and coma. Lastly, valproate can cause a hyperammonemic encephalopathy without overt liver injury.30 The reasons for this odd array of presentations lie in valproate’s mitochondrial toxicity. Microvesicular steatosis is seen on liver biopsy and carnitine depletion is felt to play a role in the pathophysiology. Mutations in the gamma polymerase gene that codes for the predominant DNA polymerase in mitochondria may influence patient susceptibility.31

Patients with DILI also may rarely present with non-cirrhotic portal hypertension and associated variceal bleeding and/or ascites, but preserved hepatic synthetic function. Nodular regenerative hyperplasia (NRH) may be present on needle biopsy, but other times histology is unrevealing. Several medications including oral contraceptives, antineoplastics, and immunosuppressives have been implicated. Due to the indolent development of portal hypertension from stellate cell stimulation and liver regeneration, latency periods can be long. Azathioprine, which has been associated with NRH, remains a mainstay treatment for inflammatory bowel disease and autoimmune hepatitis. Oxaliplatin is commonly used for stage III colon cancer and has also recently been associated with significant portal hypertension in the absence of overt liver inflammation or synthetic dysfunction.32,33 Both drugs also have been linked to sinusoidal obstructive syndrome.

Sinusoidal obstructive syndrome (SOD) usually presents more abruptly with evidence of portal hypertension and signs of hepatic dysfunction, but liver biochemistries may be only mildly elevated. Sinusoidal obstructive syndrome is typically associated with myeloablative chemotherapy given for hematologic malignancies, but other chemotherapeutic agents given for other diseases have also been implicated.34 Sinusoidal obstructive syndrome typically presents with right upper-quadrant pain, weight gain, jaundice, and hepatomegaly of varying severity. Ascites may or may not be present. Although drug latency is usually short (i.e., 20–30 days), the diagnosis can be difficult to confidently establish because these patients are often at risk for other causes of liver injury including opportunistic infections, sepsis, ischemia, and exposure to other hepatotoxic medications including antifungals and antibacterials. Furthermore, it may be difficult to distinguish early graft versus host disease from delayed SOD. Two diagnostic criteria have been published for SOD, but still 10–20% cannot be diagnosed definitely without a biopsy.35,36

**Diagnostic Evaluation of Suspected Drug-Induced Liver Injury**

Drug-induced liver injury diagnosis depends on obtaining a meticulous history and thoughtful use of diagnostic tests. However, making this effort upfront can save weeks in
<table>
<thead>
<tr>
<th>Antibiotics</th>
<th>Typical latency</th>
<th>Typical pattern of injury / identifying features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amoxicillin/clavulanate</td>
<td>1–4 wk</td>
<td>Cholestatic injury, but can be hepatocellular at initial presentation</td>
</tr>
<tr>
<td>Isoniazid</td>
<td>1–6 mo</td>
<td>Acute hepatocellular injury similar to acute viral hepatitis</td>
</tr>
<tr>
<td>Sulfamethoxazole/trimethoprim</td>
<td>Short to moderate (&lt; 4 wk)</td>
<td>Cholestatic injury, but can be hepatocellular; often with immunomodulatory features (e.g., rash, eosinophilia)</td>
</tr>
<tr>
<td>Fluoroquinolones</td>
<td>Short (1–14 d)</td>
<td>Equally hepatocellular, cholestatic or mixed</td>
</tr>
<tr>
<td>Nitrofurantoin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute form (rare)</td>
<td>Short</td>
<td>Hepatocellular</td>
</tr>
<tr>
<td>Chronic form</td>
<td>Moderate to Long (mo–y)</td>
<td>Typically hepatocellular and often identical to autoimmune hepatitis</td>
</tr>
<tr>
<td>Minocycline</td>
<td>Moderate to Long</td>
<td>Hepatocellular and often identical to autoimmune hepatitis</td>
</tr>
<tr>
<td>Antiepileptics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenytoin</td>
<td>Short to moderate</td>
<td>Hepatocellular, mixed or cholestatic often with immunomodulatory features (e.g., rash, eosinophilia)</td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>Moderate</td>
<td>Hepatocellular, mixed or cholestatic often with immunomodulatory features</td>
</tr>
<tr>
<td>Lamictal</td>
<td>Moderate</td>
<td>Hepatocellular often with immunomodulatory features</td>
</tr>
<tr>
<td>Valproate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyperammonia</td>
<td>Moderate to long</td>
<td>Elevated ammonia, encephalopathy</td>
</tr>
<tr>
<td>Hepatocellular</td>
<td>Moderate to long</td>
<td>Hepatocellular</td>
</tr>
<tr>
<td>Reye-like syndrome</td>
<td>Short to moderate</td>
<td>Hepatocellular, acidosis; microvesicular steatosis on biopsy</td>
</tr>
<tr>
<td>Analgesics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsteroidal anti-inflammatory agents</td>
<td>Moderate to long</td>
<td>Hepatocellular injury</td>
</tr>
<tr>
<td>Immune modulators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interferon β</td>
<td>Moderate to long</td>
<td>Hepatocellular, female predominance</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methotrexate (oral)</td>
<td>Long (&gt; 1 y)</td>
<td>Fatty liver, fibrosis</td>
</tr>
<tr>
<td>Allopurinol</td>
<td>Short to moderate</td>
<td>Hepatocellular or mixed. Often with immunomodulatory features; granulomas on biopsy</td>
</tr>
<tr>
<td>Amiodarone (oral)</td>
<td>Moderate to long</td>
<td>Hepatocellular, mixed or cholestatic; macrovesicular steatosis on biopsy</td>
</tr>
<tr>
<td>Androgen-containing steroids</td>
<td>Moderate to long</td>
<td>Cholestatic. Can present with peliosis hepatitis, nodular regenerative hyperplasia or hepatocellular carcinoma</td>
</tr>
<tr>
<td>Inhaled anesthetics</td>
<td>Short</td>
<td>Hepatocellular. May have immunomodulatory features ± fever.</td>
</tr>
<tr>
<td>Gastrointestinal Medications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interferon alpha</td>
<td>Moderate</td>
<td>Hepatocellular, autoimmune hepatitis-like</td>
</tr>
<tr>
<td>Anti-tumor necrosis factor agents</td>
<td>Moderate to long</td>
<td>Hepatocellular. Can have autoimmune hepatitis features</td>
</tr>
<tr>
<td>Azathioprine</td>
<td>Moderate to long</td>
<td>Cholestatic or hepatocellular, but can present with portal hypertension (veno-occlusive disease, nodular regenerative hyperplasia)</td>
</tr>
<tr>
<td>Macrolides</td>
<td>Short</td>
<td>Hepatocellular, but can be cholestatic</td>
</tr>
<tr>
<td>Sulfasalazine</td>
<td>Short to moderate</td>
<td>Mixed, hepatocellular, or cholestatic; often with immunomodulatory features</td>
</tr>
<tr>
<td>Proton pump inhibitors</td>
<td>Short</td>
<td>Hepatocellular; very rare</td>
</tr>
</tbody>
</table>

*Short = 3–30 days, Moderate = 30–90 days, Long > 90 days unless otherwise specified.*
diagnostic evaluation, decrease morbidity, and avoid unnecessary tests. Overall, the assessment focuses on four major areas: (1) timing (exposure or latency; recovery or dechallenge), (2) pattern of liver biochemistries at presentation, (3) hepatotoxicity profile of suspect agent, and (4) exclusion of competing causes. Judicious use of blood tests and liver imaging are necessary, but liver biopsy, while often helpful, is not mandatory. Drug-induced liver injury assessment has been organized into diagnostic scoring systems\textsuperscript{37–39} that are useful in organizing data into a categorical framework. However, they are not widely used in practice due to lack of proven reliability and accuracy. Others have published more complete lists of necessary clinical data that can serve as a checklist for the clinician (\textit{Table 2}).\textsuperscript{40,41}

The importance of getting accurate timing of medication start and stop dates (exposure), onset of symptoms, or liver biochemistry abnormalities (latency) and liver recovery (dechallenge) cannot be overemphasized. Such timing information is the initial parameter for all diagnostic algorithms\textsuperscript{37,39} because inaccurate exposure data will undermine any final diagnosis. For prescription drugs, contacting the patient’s pharmacy can be invaluable in defining exposure and completeness of all medications taken.\textsuperscript{42} Nowadays, getting a complete medication list also includes asking patients about herbal and dietary supplement (HDS) use; supplements are taken by over 50% of the U.S. population.\textsuperscript{43} Recent data suggest HDS hepatotoxicity attributed to body building supplements, weight loss products, and other formulations containing various amounts of potentially hepatotoxic ingredients (e.g., catechins) is on the rise in the United States.\textsuperscript{44,45} Determining onset of signs or symptoms is particularly challenging because a patient’s memory can be

\begin{table}
\centering
\begin{tabular}{|l|l|}
\hline
Element & Comments \\
\hline
Gender & Pertinent for some competing disorders (e.g., PBC) \\
\hline
Age & Pertinent for some competing disorders (e.g., HEV) \\
\hline
Race/ethnicity & Pertinent for some competing disorders (e.g., sarcoidosis, sickle cell-related liver injury, oriental sclerosing cholangitis) \\
\hline
Indication for suspect drug or HDS use & May have underlying liver disease (hypoglycemic agents in diabetics, weight-loss products in obese, etc.) \\
\hline
Concomitant diseases & Particularly pertinent disorders may include sepsis, heart failure, hypotension episodes, recent general anesthesia, parenteral nutrition, and cancer \\
\hline
Presence of rechallenge & Give timing of rechallenge if done \\
\hline
History of other drug reactions & Certain cross reactivities may exist (e.g., antiepileptics) \\
\hline
History of other liver disorders & Chronic viral hepatitis, NAFLD, hemochromatosis, alcoholic liver disease, PSC, PBC, liver cancer \\
\hline
History of alcohol use & Past versus present; estimated grams per day; sporadic versus binge drinking versus regular (daily or weekly) \\
\hline
Exposure time & Start and stop dates or total number of days, weeks, or months taken. \\
\hline
Symptoms & signs & Presence or absence, time of onset, type (fatigue, weakness, abdominal pain, nausea, dark urine, icterus, jaundice, pruritus, fever, rash) \\
\hline
Physical findings & Fever, rash, hepatic tenderness, signs of chronic liver disease \\
\hline
Medications & HDS products & Complete list of medications or HDS products with particular attention to those started in the previous 3–6 mo \\
\hline
Laboratory results & Day of first abnormal liver biochemistry; liver biochemistries, eosinophil counts at presentation \\
\hline
Viral hepatitis serologies & Anti-HAV IgM, HBsAg, anti-HBc IgM, anti-HCV, HCV RNA \\
\hline
Autoimmune hepatitis serologies & ANA, antismooth muscle antibody, IgG level \\
\hline
Imaging & US ± Doppler, CT, or MRI ± MRCP \\
\hline
Histology if available & Timing of biopsy in relation to enzyme elevation and drug-induced liver injury onset \\
\hline
Washout (dechallenge) data & Follow-up liver biochemistries over 3–6 mo after drug discontinuation \\
\hline
Clinical outcome & Resolution versus chronicity, transplant, death, and timing of each \\
\hline
\end{tabular}
\caption{Minimum elements of a diagnostic evaluation in patients with suspected drug-induced liver injury}
\end{table}
vague and subject to recall bias. Interviewing family and friends may be necessary, and recall cues used in epidemiology research can be helpful.45,46

The pattern of liver biochemistry elevations at presentation is seen only to a good history in diagnostic importance. Elevations are often categorized by the R value (R = [ALT value/ALT upper limit of normal]-[alkaline phosphatase (AP) value/AP upper limit of normal]).47 R values of > 5 are considered hepatocellular, < 2 cholestatic, and 2–5 mixed. These cutoffs are somewhat arbitrary and R values can also change as the injury progresses, particularly from hepatocellular to cholestatic pattern over time.38 Nevertheless, they serve as a useful way to focus a diagnostic evaluation on particular hepatotoxic agents and competing diagnoses.

**Likelihood of Liver Injury from a Drug**

Knowledge of the likelihood that a given drug can cause hepatotoxicity is important when assessing a patient with possible DILI. Overall, antibiotics and antiepileptics are most commonly reported accounting for up to 60% of DILI.1 Therefore, the appearance of either of these two classes of agents on a medication list should heighten one’s suspicion for DILI. On the other hand, antihypertensive and diabetic medications are less commonly reported.1 Certain offenders have signature presentations (e.g., amoxicillin-clavulanate, isoniazid, phenytoin), and Table 1 lists the most notorious as well as commonly prescribed agents including those often prescribed by gastroenterologists. For example, isoniazid injury is virtually always hepatocellular and fluoroquinolone injury typically has a very short latency. Idiosyncratic DILI inherently offers few generalizations across all medications, but a recent study suggests drugs given in daily doses exceeding 100 mg/d and those that are more lipophilic may be more likely to cause hepatotoxicity.49,50

Staying abreast of less well-known or newly reported agents associated with DILI is more difficult with the Food and Drug Administration (FDA) having approved an average of 90 drugs per year from 2007–2011 alone.51 Published DILI cases are spread across subspecialty, toxicology, pharmacology, and gastroenterology journals. Recently, the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) and the National Library of Medicine (NLM) launched LiverTox (http://www.livertox.nih.gov/), a free online resource that is updated on a regular basis.52,53 Over 650 medications are included on the website and this number continues to grow. Each medication is presented in a concise and clinically useful manner. References are robust and linked to the NLM. This website has quickly become a mainstay tool for hepatologists and clinicians and is used to guide the diagnostic evaluation. References are robust and linked to the NLM. This website has quickly become a mainstay tool for hepatologists and clinicians and is used to guide the diagnostic evaluation.

**Competing Causes of Liver Injury**

Searching for more common competing diagnoses of liver injury based upon the laboratory profile at presentation is also important. Hepatocellular injuries prompt suspicions of viral hepatitis, ischemia, and autoimmune hepatitis. A detailed alcohol history is critical when the transaminase pattern (modest elevation; aspartate aminotransferase [AST] > 2x ALT) is consistent with alcoholic hepatitis. A rapid rise and fall of serum aminotransaminase levels are hallmarks for ischemic injury. Autoimmune hepatitis (AIH) is often one of the more difficult competing diagnosis to eliminate because like DILI there is no single objective diagnostic test for AIH.54 Budd-Chiari syndrome can also present with acute hepatocellular injury and should be pursued with appropriate imaging studies (e.g., Doppler ultrasound, computed tomography or magnetic resonance imaging).

Such diagnostic evaluation of hepatocellular enzyme elevation is well known to the gastroenterologist. However, there are some noteworthy diagnoses that masquerade as DILI. Even though 10,000 new infections occur in the United States annually, acute hepatitis C is often overlooked because gastroenterologists are more accustomed to seeing the indolent chronic phase of infection, and diagnostic test results are variable in acute infection. Very early in infection, hepatitis C virus (HCV) antibody can be negative, and HCV RNA testing may be necessary. Detectable HCV RNA without antibody is consistent with acute infection. Seroconversion in the following 4 to 12 weeks with or without loss of HCV RNA would be strong evidence for acute infection, particularly if a recent risk factor were identified. Ultimately, repeat history taking for hepatitis C risk factors and retesting of HCV antibody and RNA in 4 to 12 weeks should be done, but are often forgotten. Pursuing the diagnosis of acute hepatitis C takes on added importance as we enter an era of more tolerable and curative therapies.

Cytomegalovirus (CMV) and Epstein Barr virus (EBV) hepatitis are uncommon in the immunocompetent host,55 but hepatocellular liver enzyme elevation in systemic CMV infection is often seen.56,57 Herpes simplex virus (HSV) hepatitis patients are frequently younger, with high fever and can have quite severe or fatal liver injury.58 Immunocompromised patients are more at risk, but cases in the immunocompetent are described.59 All three have acute serologic panels as well as polymerase chain reaction (PCR) testing available. No studies have looked systematically at how often suspected DILI cases are actually HSV, EBV, or CMV hepatitis. Therefore, these viral infections should be considered in cases with suggestive symptoms (e.g., fever, lymphadenopathy, splenomegaly, herpetic lesions). For all viral infections, antibody testing may be less sensitive in the immunocompromised host and nucleic acid testing should be done.

Hepatitis E is uncommon in North America and Western Europe, but has been documented to masquerade as DILI. Dalton and colleagues suggested a 12% acute hepatitis E rate in 47 cases thought to be DILI from the United Kingdom and New Zealand based on hepatitis E virus (HEV) IgG and IgM serologies.60 The DILIN retrospectively searched its registry for evidence of acute hepatitis E in 318 cases. All nine cases with positive HEV serologies were tested for HEV RNA, and re-evaluated by the DILIN group for likelihood of DILI versus HEV. Seven (2%) were felt to be more likely acute hepatitis E.
than DILI after re-evaluation. These cases of unsuspected acute HEV were predominantly in men over 50 years of age in both studies. Although the zoonotic spread of HEV from pigs, boar, and deer is postulated, a strong epidemiologic link is lacking. Outbreaks associated with travel to endemic areas (e.g., Southeast Asia, Asian subcontinent, Africa, and Mexico) are seen. Currently, tests for anti-HEV IgG and IgM levels are commercially available, but not FDA approved. In addition, testing for HEV RNA by PCR is not available in the United States. Therefore, routinely testing for anti-HEV cannot be recommended at this time, but may be considered if there is a potential exposure history (e.g., recent travel to endemic regions).

Although rare, Wilson disease is often considered as a competing diagnosis during the workup for acute hepatocellular injury particularly when acute liver failure (ALF) is present. Diagnostic guidelines for Wilson disease are available, but if ALF is present, then the ratios of AP:bilirubin < 4 and AST:ALT > 2.2 have shown better diagnostic accuracy.

Cholestatic injuries prompt concerns for biliary problems such as choledocholithiasis, pancreaticobiliary tumors, strictures, and infiltrating cancer. Evaluation for these disorders is commonplace for the gastroenterologist. Guidelines for the role of endoscopic retrograde cholangiography (ERC) and endoscopic ultrasound (EUS) in the evaluation and treatment of primary biliary cirrhosis (PBC) and primary sclerosing cholangitis (PSC) are also familiar to the gastroenterologist and diagnostic guidelines are available.

The differential and diagnostic evaluation of patients with acute liver injury pattern is broader. Such mixed pattern liver biochemistries can be particularly challenging because transition from predominantly hepatocellular to cholestatic injury can occur. A patient may present late with cholestatic enzyme elevation and the prior elevation of transaminases was missed. Here the latency between symptom onset and first testing of liver enzymes may be a helpful clue.

### Liver Biopsy

A diagnosis of DILI does not require a liver biopsy, but a biopsy can be helpful in confirming a clinical suspicion of DILI and helping to exclude competing etiologies. Some histologic findings may be quite suggestive of possible DILI and textbook descriptions of these are available. Kleiner et al recently catalogued the histologic findings from 249 consecutive DILIN cases and found most (83%) fall into six major categories of injury (acute hepatitis, chronic hepatitis, acute cholestasis, chronic cholestasis, zonal necrosis, and cholestatic hepatitis). Interestingly, the correlation with the R value was not very strong with significant overlap of R values across the histologic categories. However, certain histologic findings such as necrosis, fibrosis, and microvesicular steatosis were associated with worse outcomes, whereas granulomas and

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**Table 3** Clinical phenotypes of drug-induced liver injury, histologic features, and exemplary agents

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Histological features</th>
<th>Example agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute fatty liver with lactic acidosis</td>
<td>Microvesicular hepatic steatosis ± other tissue involvement</td>
<td>Didanosine, Fialuridine, Valproate</td>
</tr>
<tr>
<td>Acute hepatic necrosis</td>
<td>Collapse and necrosis of liver parenchyma</td>
<td>Isoniazid</td>
</tr>
<tr>
<td>Autoimmune-like hepatitis</td>
<td>Plasma cells &amp; interface hepatitis with detectable autoantibodies</td>
<td>Nitrofurantoin, Minocycline</td>
</tr>
<tr>
<td>Bland cholestasis</td>
<td>Balloon hepatocytes with minimal inflammation</td>
<td>Anabolic steroids</td>
</tr>
<tr>
<td>Cholestatic hepatitis</td>
<td>Balloon hepatocytes with inflammation, predominance of serum alkaline phosphate elevation (phenytoin, amoxicillin-clavulanate)</td>
<td>Phenytoin, Amoxicillin-clavulanate</td>
</tr>
<tr>
<td>Fibrosis/ cirrhosis</td>
<td>Hepatic collagdenization with minimal inflammation</td>
<td>Methotrexate, Amiodarone</td>
</tr>
<tr>
<td>Immunoallergic hepatitis</td>
<td>Eosinophilic infiltrate</td>
<td>Trimethoprim-sulfamethoxazole</td>
</tr>
<tr>
<td>Nodular regeneration</td>
<td>Micro- or macroscopic liver nodules</td>
<td>Azathioprine, Oxaliplatin</td>
</tr>
<tr>
<td>Nonalcoholic fatty liver</td>
<td>Macro- and microsteatosis, hepatocyte ballooning and periportal inflammation</td>
<td>Tamoxifen</td>
</tr>
<tr>
<td>Sinusoidal obstruction syndrome</td>
<td>Inflammation with obliteration of central veins</td>
<td>Busulfan</td>
</tr>
<tr>
<td>Vanishing bile duct syndrome</td>
<td>Paucity of interlobular bile ducts</td>
<td>Sulfonamides, Beta-lactams</td>
</tr>
</tbody>
</table>
Clinical Spectrum and Diagnosis of Drug-Induced Liver Injury

The low incidence and heterogeneity of DILI makes research into its natural history difficult, but large registries and population-based studies are beginning to clarify this issue. In Iceland, the crude overall annual incidence of idiosyncratic DILI was 19.1 case per 100,000 population, which is similar to the rate reported previously in northern France. Three registries from Sweden, Spain, and the United States totaling over 1,500 patients reported 6 to 9% having a severe outcome of death or need for liver transplantation within 6 months. Risk of such early adverse outcome was highest in those with acute hepatocellular injury (7–13%) and lowest with a mixed pattern (2%). However, within these overall severe outcome rates there was wide variation between drugs. In the Swedish registry, both isoniazid and halothane cases of hepatocellular injury had 40% rates of death or transplantation, whereas no such severe outcomes were seen with erythromycin. Across all three studies, elevated bilirubin at presentation was associated with early severe outcome. Therefore, patients presenting or developing jaundice early in their liver injury deserve close follow-up and perhaps early consultation with a transplant center, particularly if the injury pattern is hepatocellular.

For those that do not have an early severe outcome, the course is less clear although most patients are expected to have a full recovery. Indeed, DILI has typically been considered an outcome of extremes from early mortality or need for transplantation on one end and complete recovery on the other. However, even as early as 1999, a study of just 33 patients suggested that chronic damage on biopsy may occur during prolonged follow-up. Case reports of vanishing bile duct syndrome after a DILI episode are also reported. More recent registry data suggest chronic liver injury does occur, but the reported rate is highly dependent on how it is defined. At this point there are no accepted definitions for “chronic...
DILI," hence the literature in this area is unclear but evolving. In the Sweden registry, 685 patients surviving the first few months after their DILI episode were linked to their national Cause of Death Registry and Hospital Discharge Registry. Follow-up spanned a remarkable median of 11 years (range 3–23). Twenty-three patients (3.4%) were diagnosed with liver disease during a hospitalization or at death, and medical charts reviewed. Of these 23, perhaps 10 (1.4%) had chronic DILI based on chart review indicating no other obvious etiology for their liver disorder. Such criteria based on hospitalization and/or death registration will obviously underesti-

mate the rate by excluding those with less severe course and followed in an outpatient setting.

When chronic DILI is defined more broadly as persistent elevations in liver enzymes, the rate is expectedly higher. In the Spanish registry, chronic DILI was defined as persistently elevated liver biochemistries at 3 months post-DILI for hepatocellular and 6 months for cholestatic or mixed injuries. Here, the overall rate of chronicity was 5.7%. In the U.S. DILIN registry, 18% had persistent elevations at 6 months including all patterns of injury. The clinical and histologic outcome of such patients remains unclear. Moreover, subsequent

### Table 4 Roussel Uclaf causality assessment model (RUCAM) causality assessment method

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Hepatocellular</th>
<th>Cholestatic or mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enzyme pattern</strong></td>
<td>Initial exposure</td>
<td>Subsequent exposure</td>
</tr>
<tr>
<td><strong>Exposure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5–90 days</td>
<td>+2</td>
<td>5–90 days</td>
</tr>
<tr>
<td>1–15 days</td>
<td></td>
<td>1–90 days</td>
</tr>
<tr>
<td><strong>Timing from</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;15 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;=15 days</td>
<td>+1</td>
<td>&lt;=30 days</td>
</tr>
<tr>
<td><strong>Drug start</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;=15 days</td>
<td>+1</td>
<td>&lt;=30 days</td>
</tr>
<tr>
<td><strong>Drug stop</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;=15 days</td>
<td>+1</td>
<td>&lt;=30 days</td>
</tr>
<tr>
<td><strong>Course</strong></td>
<td>Difference between peak ALT and upper limit normal (ULN) value</td>
<td>Difference between peak AP (or bili) and upper limit normal (ULN)</td>
</tr>
<tr>
<td><strong>After drug stop</strong></td>
<td>Decrease &gt;=50% in 8 days</td>
<td>Decrease &gt;=50% in 180 days</td>
</tr>
<tr>
<td><strong>Risk factor</strong></td>
<td>Ethanol: yes</td>
<td>Ethanol or pregnancy: yes</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>&gt;=55</td>
<td>&gt;=55</td>
</tr>
<tr>
<td><strong>Other drugs</strong></td>
<td>None or no information</td>
<td>None or no information</td>
</tr>
<tr>
<td><strong>Competing causes</strong></td>
<td>All Group Ia &amp; IIb ruled out</td>
<td>All Group Ia &amp; IIb ruled out</td>
</tr>
<tr>
<td><strong>Previous information</strong></td>
<td>Reaction in product label</td>
<td>Reaction in product label</td>
</tr>
<tr>
<td><strong>Rechallenge</strong></td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Compete causes</strong></td>
<td>All Group Ia &amp; IIb ruled out</td>
<td>All Group Ia &amp; IIb ruled out</td>
</tr>
<tr>
<td><strong>Previous information</strong></td>
<td>Reaction published; no label</td>
<td>Reaction published; no label</td>
</tr>
<tr>
<td><strong>Rechallenge</strong></td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Risk factor</strong></td>
<td>Ethanol: yes</td>
<td>Ethanol or pregnancy: yes</td>
</tr>
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<td><strong>Age</strong></td>
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</tr>
<tr>
<td><strong>Rechallenge</strong></td>
<td>Positive</td>
<td>Positive</td>
</tr>
</tbody>
</table>

\(^a\)Group I, HAV, HBV, HCV (acute), biliary obstruction, alcoholism, recent hypotension (shock liver).

\(^b\)Group II, CMV, EBV, herpes virus infection.

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Clinical Spectrum and Diagnosis of Drug-Induced Liver Injury

Hayashi, Fontana
development of non-DILI liver disease such nonalcoholic fatty liver disease and prolonged resolution of biochemistries beyond 6 months will need to be considered moving forward. Nevertheless, data suggest chronic DILI whether by immune-mediated injury, vanishing bile ducts, or some other pathophysiology, does exist and may portend future liver-related problems for some.

Thus, the natural history of DILI is dominated by complete recovery for most, but roughly 10% may not survive the initial injury or may require liver transplantation. Another 5 to 10% may be at risk for chronic injury and perhaps long-term morbidity and mortality. The role of clinical cofactors (e.g., NAFLD) and comorbidities (e.g., diabetes) in the risk of developing chronic DILI requires further investigation. Clearly, heterogeneity in hepatotoxic agents and host susceptibility factors play important roles in both early severe outcome and chronic injury. For now, the clinician should be aware of the medications, signs, and symptoms indicating increased risk of early severe outcome. And for the majority of patients surviving the initial injury, the clinician must remember that some may not fully resolve and deserve follow-up.

Conclusion

The clinical manifestations, diagnosis, and natural history of idiosyncratic DILI remain a challenge for the busy gastroenterologist. Despite its low incidence in the general population, DILI remains a common request for gastroenterology consultation both in the inpatient and outpatient setting. Without objective diagnostic tests, clinicians must rely heavily on history taking skills, awareness of the hepatotoxicity risk for various agents, in-depth knowledge of clinical presentation, and evaluation for competing etiologies. Occasionally, DILI may be severe or life-threatening, and risks factors for such must be recognized quickly to provide appropriate care. Thereafter, a minimum of 6 months follow-up to assess for possible chronic injury is necessary. All this takes time, which can be at a premium for the busy clinician. Better diagnostic tools and epidemiologic data will make DILI identification and care easier in the future. For now, the clinician may want to keep the RUCAM (Table 4) or a clinical checklist (Table 2) close at hand and refer to the LiverTox website for guidance on particular agents.

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