Clinical Practice Guidelines

EASL Clinical Practice Guideline: Occupational liver diseases

European Association for the Study of the Liver*

Summary
A variety of chemicals have been linked to occupational liver diseases, including solvent vapours and other exposures such as pesticides, and metals. Workplace exposures have been associated with virtually the entire spectrum of acute and chronic liver diseases. However, their prevalence is inadequately quantified and their epidemiology limited. Occupational liver diseases may result from high accidental or from prolonged lower level exposures. Whereas the former is uncommon and easily recognised, the latter are relatively more frequent but often overlooked because they may display normal values of conventional markers, have an insidious onset and be asymptomatic or be obfuscated and confounded by concurrent conditions. In addition, specific tests of toxicity are not available, histopathology may not be revealing and the assessment of internal dose of chemicals is usually not decisive. Given these circumstances, the diagnosis of these disorders is challenging, one of exclusion and often requires an interdisciplinary approach. These recommendations offer a classification of the type of liver injuries associated with occupational exposures – based in part on the criteria for drug-induced liver injury – a grading of their severity, and the diagnostic and preventive criteria for chemically induced occupational liver disease.

Introduction
Occupational exposures can induce liver injury in a similar way to prescription drugs, herbal and dietary supplements, and workplace exposure has been implicated in the full spectrum of liver disease. However, the awareness of hepatologists for this specific aetiology of liver injury is limited and the incidence and prevalence of occupational liver diseases (OLDs) remains unknown. Acute liver injury is likely to decrease, at least in high income countries, given the improvement in health and safety in workplaces achieved over the recent years. Unpredictable routes of exposure such as breakdown, cleaning and maintenance of machinery, and accidental leakage still occur though new causes of OLD will potentially come to light, such as liver silicosis, particulate matter air pollution and increasing use of nanomaterials. Moreover, the diagnosis of OLD remains challenging in clinical practice due to the lack of pathognomonic signs and sensitive biomarkers of liver injury. Whilst acknowledging that viral infections in hospital workers are recognised as OLDs, herein, attention will only be paid to chemically induced liver injuries.

These recommendations are intended to provide standardisation of nomenclature, definitions and classification of the type of liver injuries, based in part on the criteria for drug-induced liver injury (DILI), which attempt to grade their severity. The main focus will be to increase awareness of OLDs within the medical community and to improve recognition and management of affected patients in a consistent manner.

Due to the absence of data on observational studies and meta-analyses or systematic reviews, the evidence and recommendations in these guidelines have been graded according to the Oxford Centre for Evidence-based Medicine, which assesses evidence according to diagnostic, prevalence, aetiological, prognostic or preventive categories, and – even when the evidence is inconclusive – can still generate grades of recommendation. This follows the recent recommendations for European Association for the Study of the Liver (EASL) Clinical Practice Guidelines (CPGs).

This CPG has been developed along a 2-year mandate by a panel of experts chosen by the EASL Governing Board who had 3 face to face meetings. This included experts in hepatology, toxicology, pharmacology, pathology, occupational medicine and epidemiology. Conflicts of interest were declared as requested, and consensus was reached by discussion, whenever required. The recommendations were peer-reviewed by external expert reviewers and approved by the EASL Governing Board. The CPG was developed using data collected from PubMed and Cochrane database searches up to December 2018. The searches were conducted using the terms “liver diseases”, “occupational”, “hepatotoxicity”, “toxicants”, “vinyl chloride”, “TASH”, “NAFLD”. Papers were searched for additional references. No other restrictions were applied. This CPG is based, as far as possible, on evidence from existing publications and, when unavailable, the authors provided personal experiences and opinions and reached an unanimous expert consensus.

Epidemiology
Despite the well-documented presence of multiple potentially hepatotoxic chemicals at a variety of workplaces (e.g., agricultural, hospitals, dry cleaning shops, chemical factories covering polymer synthesis, resins, leather and printing) the prevalence of OLD is unknown. We will address the role of occupational risk factors as they contribute to non-malignant and malignant liver...
Non-malignant liver diseases
In a population survey of over 13,700 workers from Taiwan, higher prevalence rates of self-reported unspecified "liver disease" were observed among blue-collar or unskilled workers, although notably they also reported more frequent tobacco and alcohol use, raising uncertainty about causation. Substantially higher mortality rates from non-neoplastic diseases of the liver were also reported in low versus high social class occupations in a Korean cohort of workers enrolled in the national employment insurance program between 1995 and 2000. Similarly, using 1979–1981 data, the California Occupational Mortality Study (COMS) reported a high mortality from cirrhosis among selected low social class occupations, including bartenders, loggers, laborers, roofers, construction workers, farm workers, ironworkers and painters for men, and waitresses, telephone operators, cosmetologists, dress makers, hospital orderlies, textile workers and laborers for women. Conversely, a low mortality from cirrhosis was observed among high social class occupations. An elevated mortality from cirrhosis was observed among publicans and bar staff of both sexes, and male seafarers, caterers, cooks and kitchen porters in an analysis of national English and Welsh death data. Overall, these findings point to unfavourable lifestyle factors linked to lower social class, in particular alcohol abuse and tobacco smoking, which may coexist with exposure to other occupational toxins.

However, one of the challenges can be the presence of confounding factors. As an example, an excess risk of cirrhosis following high cumulative exposure to vinyl chloride monomer (VCM) in the workplace was suggested by a re-analysis of European workers, albeit in the absence of a linear trend in risk or of an excess mortality from cirrhosis. However, incorrect associations can often be made when conclusions are drawn from single studies. A systematic review and meta-analysis including data from the aforementioned European multicentre study, along with a large multicentre collaborative re-analysis from North America and 5 smaller independent cohort studies, of over 40,000 VCM-exposed workers with 203 deaths from cirrhosis, did not find any increased mortality from cirrhosis in VCM-exposed workers overall. The pooled relative risk (RR) was 0.73 (95% CI 0.61–0.83), with no evidence of heterogeneity or publication bias. Thus, the available epidemiological data do not support a relationship between occupational exposure to VCM and cirrhosis, which is in agreement with experimental studies of VCM-exposed rodents and pathology reports of VCM-exposed workers and patients with VCM-related liver angiosarcoma. These studies did not observe evidence of cirrhosis, only periportal fibrosis.

In another example, despite prior experimental data associating shift work with non-alcoholic fatty liver disease (NAFLD), a cross-sectional study based on multiple cycles of the National Health and Nutrition Examination Survey (NHANES) cohort found no evidence of an association when comparing 1,019 shift-workers with 8,159 other adults (odds ratio 1.11, 95% CI 0.87–1.43). Circadian disruption (jet lag) has been related to hepatocellular carcinoma (HCC) in rodents, possibly through induction of NAFLD. Data on shift work and liver neoplasms in humans, however, are inconclusive. Data are insufficient to provide recommendations due to difficulties in adjusting for covariates and confounding factors.

Liver malignancies
Vinyl chloride monomer and angiosarcoma of the liver and hepatocellular carcinoma
Since the first 3 reported cases of liver angiosarcoma amongst VCM reactor cleaners in a US facility, subsequent evidence has confirmed the causative link between high occupational exposure to VCM (among autoclave workers) and angiosarcoma of the liver. In the most recent update, a collaborative re-analysis of nearly 10,000 US workers exposed to VCM reported 63 deaths from angiosarcoma of the liver, occurring after an average of 40 years of follow-up. With reference to HCC, the International Agency for Research on Cancer (IARC) concluded in 1987 that VCM exposure causes HCC. In part based on data from 2 large collaborative re-analyses of VCM-exposed European and US workers, a meta-analysis of data from these 2 large cohorts estimated a summary RR of 1.35 for liver cancers other than angiosarcomas, which was of borderline significance (95% CI 1.04–1.77). This estimate was based on 60 deaths mainly from HCC but also from liver cancer of unspecified or undefined histology, and hence possibly angiosarcomas. It is therefore unclear if the excess risk was real or due to misclassification of HCC. In any case, in 2012, the IARC confirmed its earlier conclusion on VCM exposure as a causal factor for HCC. In 2017, a US collaborative re-analysis provided results updated up to 2013 and, based on 32 deaths from the disease, found that the increased risk of HCC was restricted to workers with very high estimated cumulative exposure.
chloroethylene), a chlorinated solvent mainly used in dry cleaning, and HCC. More recently, an ecologic investigation from Texas found a positive association between the incidence of HCC and VCM concentrations in air; in this case the exposure was environmental though and not occupational. In conclusion, whilst high VCM exposure has a clear causative association with angiosarcoma of the liver, its link with HCC is not as well-established. Following the control of occupational exposure to VCM in the mid-1970s, few additional cases of VCM-related angiosarcoma of the liver are anticipated in the future. By inference, this applies to other liver cancers too.

**Recommendation**

- Surveillance with ultrasound for development of emergent liver neoplasms should be discussed for workers exposed to high levels of VCM in the past, i.e. until the mid-1970s, as defined by their job title (reactor cleaners). Grade D

**Evidence:** Extrapolation from level 2 studies (historic cohort studies)

### Controversial associations with liver cancers

**Trichloroethylene.** Trichloroethylene (TCE), which has been widely used for decades to degrease metal parts and for dry cleaning, when given at very high doses to certain strains of rats and mice can induce a variety of cancers, including liver/kidney tumours, and lymphomas. The evidence from epidemiologic studies is less clear. A meta-analysis combining results from 9 cohort studies (generally based on fewer than 10 events) found a modest association for overall TCE exposure and cancer of the liver or gallbladder/biliary tract (pooled RR 1.29, 95% CI 1.07–1.56). However, there was no consistent dose-risk relationship as the estimate for the highest TCE exposure category (RR 1.28, 95% CI 0.93–1.77) was similar to that of the overall analysis.

The pooled RR from the 3 studies providing information on liver cancer alone fell short of finding an association (pooled RR 1.25, 95% CI 0.99–1.57). A nested case-control study from the Nordic record-linkage study did not find an increased liver cancer risk among dry cleaners when TCE was the dominant solvent, in agreement with a US cohort of over 5,000 dry cleaning workers.

**Tetrachloroethylene (or perchloroethylene).** A record-linkage study from 4 Nordic countries based on census occupation information (i.e. the Nordic Country Occupational Cancer, NOCCA, study) suggested an association between occupational exposure to TCE or perchloroethylene (also named tetrachloroethylene), a chlorinated solvent mainly used in dry cleaning, and HCC.

A systematic review by the U.S. Environmental Protection Agency that included 18 studies which used different exposure-assessment approaches (e.g. individual exposure assigned using a job-exposure matrix; individuals employed only in facilities using tetrachloroethylene as the primary solvent exposure; occupational title as dry cleaner, launderer or presser as a surrogate of tetrachloroethylene exposure), did not find a consistent association, even among studies with a large number of observed events/exposed cases or a strong exposure-assessment approach.

**Polychlorinated biphenyl exposure.** A meta-analysis of occupational exposure to polychlorinated biphenyls (PCBs) found no significant association with liver cancer (pooled standardized mortality ratio [SMR] = 1.26, 95% CI 0.65–2.20), although this was based on only 12 events from 4 investigations. An excess mortality from liver, gallbladder and biliary tract cancers was detected in a cohort of US PCB-exposed workers, based on 5 deaths among men and 9 among women, but this was only significant in women. Similarly, no increase in mortality from liver cancer was reported in an updated analysis of 2 Italian occupational cohorts. A combined analysis of the 3 largest US capacitor manufacturing cohorts, including over 24,865 workers exposed to PCBs from 1938 to 1977 at plants in Indiana, Massachusetts, and New York; with 63 deaths from liver, biliary tract and gallbladder cancer also found no excess liver cancer mortality overall (SMR 0.98, 95% CI 0.76–1.26), irrespective of longer (≥90 days of employment) or higher cumulative PCB exposure (≥600,000 unit-days).

Thus, epidemiologic evidence does not support an association between occupational exposure to PCBs and liver cancer risk. Yet, PCBs are currently classified as Group 1 “Carcinogenic to humans” by IARC, largely based on evidence of melanoma risk in humans.

**Pesticides.** In the Agricultural Health Study cohort, there was an excess HCC risk in metolachlor (a widely used herbicide) users, but there were only 23 exposed cases, and the RR for the highest intensity-weighted lifetime days exposure category was significant only when non-exposed applicators were used for comparison (RR = 3.18, 95% CI 1.10–9.22). Other herbicides and pesticides were occasionally associated with slight changes in liver function and enzymes, and also to HCC risk, but the evidence was inconsistent.

In a systematic review from 2015, including 15 studies on pesticide exposure and liver cancer (mainly HCC), most studies, particularly those relying on self-reported exposure and occupation, job-exposure matrices, and rural residence, found no association. In addition, a Canadian cohort of over 2 million agricultural workers found, if anything, a reduced liver cancer occurrence. However, biomarker-based studies conducted on Chinese populations suggested that certain organochlorine serum levels, mainly of dichlorodiphenyl trichloroethane (DDT), may be associated with an increased liver cancer risk.

Various jobs. In a cohort of over 8 million Koreans followed for an average of 11 years, higher mortality rates from liver and intrahepatic bile duct cancers were observed in both male and female of lower social class groups. Similarly, male cooks and kitchen porters, caterers, publicans and bar staff, and seafarers had a higher mortality from liver cancer in an analysis of national mortality data from England and Wales, which has been attributed to higher levels of alcohol consumption in those occupations compared to the general population.

A record-linkage study of 15 million adults from 5 Nordic countries identified 17,730 HCC cases in men and 10,973 in women in the 1960–90 censuses that were followed-up until 2005. Of note, the highest standardised incidence ratios (SIR) in men were
observed among waiters (4.22, 95% CI 3.47–5.13), cooks and stewards (SIR = 2.6, 95% CI 1.9–3.3) and beverage workers (SIR = 2.5, 95% CI 1.85–3.31). Other significant high-risk job categories included journalists, seamen, administrators, sale/ shop workers, plumbers and economically inactive subsets. In women, excess risks were seen amongst smelting workers (SIR = 2.11, 95% CI 1.09–3.68), tobacco workers (SIR = 2.04, 95% CI 1.08–3.48), waitresses (SIR = 1.36), launderers and dry cleaners (SIR = 1.27) and building caretakers (SIR = 1.21). Whilst the pattern of high-risk occupations in men largely reflects the high frequency of alcohol consumption and other known lifestyle risk factors for HCC (e.g. tobacco and hepatitis), chemical factors may at least in part contribute to the highest SIR observed in women. Based on Finnish data, Lindbohm et al. reported excess risks of liver cancer among workers highly exposed to chlorinated hydrocarbons and other solvents, though based on a limited number of exposed individuals. Similarly, an excess of liver cancer was observed in a Danish cohort of 15,534 men and 3,593 women working in the printing industry in 1970. A US case-control study conducted in 1975–1980 and including 265 HCC cases, found an excess liver cancer risk for male farm labourers and males employed in winemaking, gasoline service stations, laundring, bartenders and other eating and drinking places. Another US retrospective study with over 1,700 deaths from liver cancer found an increased risk for oil refinery workers, plumbers and pipe fitters, textile workers, butchers and meat cutters and cooks. Similarly a Danish nested case-control study with almost 1,000 liver cancer cases found an excess risk in a large number of industries, including the printing industries and among employees with easy access to alcoholic drinks. A follow-up study based on the Swedish Family-Cancer Database found increased liver cancer risks for male sales agents, journalists, seamen, waiters, cooks and female beverage manufacture workers. Two case-control studies, 1 in Italy and 1 in France, also found associations between HCC and employment in repair of motor vehicles, and metal machining jobs. A Japanese study on 51 offset colour proof-printing workers exposed to 1,2-dichloropropane and/or dichloromethane reported 11 cases of cholangiocarcinoma. Despite this cluster, no further reports are available on 1,2-dichloropropane and/or dichloromethane.

A narrative review reported associations between polycyclic aromatic hydrocarbons and liver cancer, besides solvents and asbestos, with however inconsistent findings across original reports, and unsatisfactory mechanistic justification for asbestos. There were also scattered reports of an association between heavy metals and NAFLD.

We should call for raised attention on unexpected clusters of OLD and new work-related health risks in general, as the only way to establish epidemiological links is to have such reports made publicly available.

The available evidence does not support recommendations for screening for liver cancers in trichloroethylene and other chlorinated solvent-exposed workers, workers exposed to polychlorinated biphenyl and workers exposed to pesticides.

The occupational setting

A wide variety of chemicals, encountered at the workplace, have been linked to liver injury. Table 1 provides a list of compounds, with the associated liver pathologies, which are further elaborated on in Section 6. Table 2 links these compounds to (typical) usages, which may be further linked to professions in which these compounds are (or can be) encountered. The latter is particularly relevant to allow a suspicion to be raised between workplace-related exposure to a liver toxicant (even when

Table 1. Pathological patterns and morphological features of liver disease associated with workplace-related toxicants.

<table>
<thead>
<tr>
<th>Pathological patterns</th>
<th>Morphological features</th>
<th>Toxicants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatocellular</td>
<td>Hepatocellular necrosis ± lobular inflammation</td>
<td>CCl₄, chloroform, toluene, TNT, PCBs, chloronaphthalene, DMF, hydrozine, 2-nitropropane, phosphorus, DMA, halothane, TCE, tetrachloroethane, 1,4-dichlorobenzene, DMF</td>
</tr>
<tr>
<td>Cholestatic/mixed</td>
<td>Cholestasis, cholangitis, Combined features</td>
<td>Methyleneedianiline, Nitrobenzene, paraquat, methylenedianiline</td>
</tr>
<tr>
<td>TAFLD</td>
<td>Steatosis (macro/microvesicular), Steato-hepatitis (steatosis + lobular inflammation + hepatocellular ballooning)</td>
<td>Chloroalkenes (PCE, TCE), VCM, chloroform, CCl₄, volatile organic compounds (benzene, toluene, styrene, xylene), dioxins, chlorodecon, DMF, hydrozine, arsenic, mercury, POPs, pesticides, and some nitro-organic compounds</td>
</tr>
<tr>
<td>Vascular</td>
<td>Sinusoidal obstruction syndrome, Proliferosis</td>
<td>VCM, dioxin, pyrrolizidine alkaloids, arsenic, copper sulfate, VCM</td>
</tr>
<tr>
<td>Chronic damage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibrosis</td>
<td>Periportal fibrosis, Extensive fibrosis/cirrhosis</td>
<td>VCM, PCBs, chloronaphthalene, Tetrachloroethane, VCM</td>
</tr>
<tr>
<td>Vascular</td>
<td>Porto-sinusoidal vascular disease (previously hepatoporal sclerosis)</td>
<td>VCM, sprays containing copper sulfate and lime</td>
</tr>
<tr>
<td>Tumors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epithelial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatocellular carcinoma</td>
<td></td>
<td>Arsenic, dimethyl nitrosamine, 1,2-Dichloropropane, dichloromethane</td>
</tr>
<tr>
<td>Cholangiocarcinoma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angiosarcoma</td>
<td></td>
<td>VCM, Arsenic</td>
</tr>
<tr>
<td>Epithelioid hemangioendothelioma</td>
<td></td>
<td>VCM</td>
</tr>
</tbody>
</table>

DMF, dimethylformamide; PCBs, polychlorinated biphenyls; POPs, persistent organic pollutants; TCE, trichloroethylene; VCM, vinyl chloride monomer.
historical – possibly a decade or more ago) and an observed disease.

**Recommendation**

- It is advisable that workers with potential exposure to hepatotoxic chemicals receive a document listing the chemicals used in the factory. Such a document may be made available to the workers without request. **Grade D**

**Evidence:** Level 5 (Expert opinion)

The National Institute for Occupational Safety and Health has published a pocket guide to hazardous chemicals. This guide can help clinicians to know if the chemicals to which the patient has been exposed are known causes of the observed liver disease.

**Host risk factors for occupational liver disease**

Understanding what makes one particular worker susceptible to develop liver injury after exposure to industrial chemicals as opposed to other co-workers who do not manifest any hepatic dysfunction is key. The answer to this question is complex. Many industrial chemicals belong to the group of so-called “intrinsic” hepatotoxins. These are substances with predictable toxicity, which dose-dependently and directly (or through activation of chemicals to toxic metabolites) produce liver damage. In practical terms, the dichotomy between intrinsic and idiosyncratic hepatotoxins is an overly simplified concept because the potential for toxic injury extends along a spectrum, modified by the toxin and host factors, involving different biochemical and immunological responses. Elaborating on this concept, the hepatotoxic potential of some chemicals, such as phosphorus or pyrrolizidine alkaloids, is closely linked to the extent of exposure and rarely to host vulnerability. On the other hand, individual susceptibility is critical in determining the probability of developing liver injury from compounds such as halothane or paracetamol. Therefore, risk assessments should also take into account host-environmental interactions that will likely modulate the severity of liver injury and add complexity to the diagnosis of OLD.

**Age and gender**

Age plays an important role for drug disposition and sensitivity to xenobiotics. As body composition changes with age, particularly in women, exhibiting a higher percentage of adipose tissue, lipophilic chemicals could enhance the risk of liver injury. However, the net effect of age as a risk modifier for OLDs is unknown.

In an experimental model, female rats exhibited a more severe phenotype of mercuric chloride-induced hepatotoxicity, as evidenced by higher increases in aminotransferases and histopathological findings. Interestingly, in patients with DILI, despite an equal sex distribution, females are at a higher risk of developing acute liver failure. Female sex might be a risk factor for chemical-induced liver injury, although robust evidence from human data is still lacking.

**Drug-chemical interactions**

Liver cytochrome P450 isozymes are responsible for the oxidative metabolism of most drugs and workplace-related xenobiotics. The concurrent administration of drugs and exposure to chemicals could either induce or inhibit microsomal activity, either directly or via the generation of reactive metabolites, thereby modifying the effect of either drug or chemical exposure. For instance, first-generation anti-epileptics are known for their enzyme inducing capacities. Hence, enzyme induction by carbamazepine, a known hepatotoxin in itself, favours chemically reactive metabolite formation from other chemicals, thereby increasing their risk of liver toxicity. This is exemplified by a carbamazepine-treated patient presenting with acute hepatitis resulting from the use of paints, paint thinner, carbon tetrachloride (CCl₄) and organic solvents in enclosed areas without ventilation, in whom the hepatotoxicity was mistakenly ascribed to carbamazepine. The predisposition to severe liver and renal injury in a worker using CCl₄ to clean paintings, probably due to microsomal induction by concomitant treatment with phenobarbital, underscores the importance of not overlooking the potential for drug/xenobiotic interactions at the workplace. Additionally, we should also keep in mind the potential of xenobiotic interactions in industry workers exposed to multiple chemicals at once. Thus, a mixed exposure to chlorinated organic solvents, including dichloromethane, 1,2-dichloropropane, and trichloroethylene, may induce a synergistic effect towards the development of severe acute hepatitis. Furthermore, in an experimental model, thinner pretreatment (methyl or toluene are the major constituents) via inhalation potentiated the hepatotoxicity induced by CCl₄ through an induction of microsome oxidases to increase the formation of free radicals and membrane lipid peroxidation.

**Recommendation**

- Caregivers, as well as workers exposed to liver enzyme inducers and/or using enzyme inducing drugs should be informed of the possibility of interactions with anti-convulsant drugs. **Grade C**

**Evidence:** Level 4 (case series)

**Genetic variations in metabolic pathways**

Genetic polymorphisms in genes encoding enzymes involved in xenobiotic metabolism (oxidation and detoxification) result in different drug levels, which can then result in variable drug effects, thus exemplifying another element that may determine an individual's susceptibility to chemical-induced liver disease. Hence, patients exhibiting a poor metaboliser genotype may show higher serum toxin concentrations and associated risk of toxicity. Hsieh et al. showed in a longitudinal study of 320 workers exposed to VCM that 13 developed liver fibrosis with those that were homozygotes for CYP2E1 variant alleles (low activity) being overrepresented in this group. However, liver injury from drugs and chemicals is a complex process, reflecting the interplay between the toxin's physicochemical properties and host factors that modulate the final response to hazardous exposures. Consequently, knowledge of genetic variability has not yet proven useful for discriminating high-risk populations.
Indeed, according to the code of ethics issued by the International Commission on Occupational Health the selection of high-risk populations upon genetic testing should be considered unethical. Instead, improving working environments is recommended.76

Alcohol
There is agreement that social habits, such as alcohol consumption, can worsen or potentiate the toxicity associated with occupational exposure to chemical substances, thus acting as a confounding factor when making a diagnosis of the role of occupational exposure (e.g. fatty liver). Notably, the prevalence of alcohol use amongst industrial workers is inferred to be high, with reports of male workers having higher consumption than females.77

It is well recognised that alcohol consumption can increase the hepatotoxic effects of other compounds taken simultaneously through its inducing effect on the cytochrome P450 system (CYP). Particularly the isoform CYP2E1.79 Indeed, high alcohol intake had a severe potentiating effect on occupational exposure to CCl₄79 and other chemicals that are activated by the same cytochrome P450 enzymes.80 Alcohol drives the generation of toxic free radical intermediates and therefore enhances the likelihood of severe CCl₄-induced liver injury.81

Pre-existing liver diseases
As exposure to some occupational toxins may induce acute or chronic liver injury, it is important to assess the functional status of patients’ livers, as toxin exposure may be worsened by underlying liver disease. However, this remains quite a controversial issue, with minimal clinical data to support the view that underlying liver disease may increase susceptibility to occupational chemicals.82

Non-alcoholic fatty liver disease
NAFLD, the most prevalent liver disease worldwide, is considered the clinic-pathological hepatic manifestation of obesity and metabolic syndrome. It is recognised that in patients with NAFLD, CYP2E1 is upregulated (like in obese patients), favouring the metabolism of toxins (like VCM) into reactive metabolites, which could ultimately increase the susceptibility to toxicant-associated steatohepatitis (TASH) development. There is experimental evidence that exposure to low doses of VCM may also sensitize the liver to other metabolic stresses and potentiate liver injury.83 Similarly, there is evidence that pre-existing NAFLD increases the risk of acetaminophen overdose-induced acute liver injury.84 Notably, patients with NAFLD were not at a higher risk of statin hepatotoxicity.85 However, a recent study in the US, using electronic medical records, showed that patients with surrogate markers of NAFLD (i.e., consistently elevated alanine aminotransferases [ALT] levels and high prevalence of hypertension, type II diabetes mellitus and obesity) had a greater incidence of suspected DILI related to the drugs most frequently involved in hepatotoxicity.86 Interestingly, drugs inducing mitochondrial dysfunction such as tamoxifen, methotrexate and irinotecan can worsen steatohepatitis in patients with metabolic syndrome and obesity.84,87 Thus, we could extrapolate from existing data that underlying NAFLD could increase susceptibility to TASH from industrial chemical exposure.88
Recommendation

- Occupational workers with classical risk factors of fatty liver may be advised by the attending physician to have a baseline screen for NAFLD/non-alcoholic steatohepatitis (NASH), alcohol-related fatty liver disease (AFLD), and alcohol-related steatohepatitis (ASH), and a close follow-up.

Evidence: Level 5 (Expert opinion)

Viral hepatitis

Nowadays, there are effective therapies for curing hepatitis C and for suppression of viraemia in patients with chronic hepatitis B. Hence, except in developing countries with limited access to these new therapies, chronic hepatitis B and C are not a concern for workers exposed to occupational chemicals. However, in patients with eradicated or controlled liver infection, residual lesions (fibrosis, steatosis) can persist. It is known that hepatitis C virus can be associated with a greater risk of diabetes, insulin resistance and consequently NAFLD. There is also a complex interplay between hepatitis B infection and NAFLD. Furthermore, regression of fibrosis with long-term viraemia suppression in patients with chronic hepatitis B undergoing tenofovir therapy has been documented, with underlying NAFLD being suggested as an explanation for those who did not experience fibrosis regression. Likewise, in patients exposed to occupational chemicals, regular alcohol intake above predefined thresholds (>20 g/day [women], >30 g/day [men]) should be investigated because it increases the risk of AFLD or ASH.

Recommendation

- A screen for the concurrent presence of NAFLD/NASH, AFLD/ASH and/or residual fibrosis is suggested in workers with cured hepatitis C or controlled chronic hepatitis B virus infection and clinical data suggestive of NAFLD/NASH, AFLD/ASH in order to better delineate their risk profile when exposed to chemicals.

Evidence: Level 5 (Expert opinion)

Definition of liver injury in occupational liver diseases

Biochemical definition of acute liver injury

Hepatic injury in a working population exposed to potential hepatotoxins is generally detected by standard liver biochemistry that reflects necro-inflammatory processes in the liver. These biomarkers are not specific for any form of toxic liver disease, lack mechanistic insight and may not confer prognostic significance. The similar clinical and histopathological features of hepatic injury observed as a consequence of the exposure to occupational chemicals and drugs, makes it appropriate to adopt the consensus criteria used for DILI. Using these criteria and by common convention, the thresholds of liver enzymes used to define acute liver injury are as follows (Table 3):

Table 3. Thresholds of liver enzymes used to define acute liver injury and pattern of damage according to Ratio (R) [4,5].

<table>
<thead>
<tr>
<th>R Value</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>≥5</td>
<td>Hepatocellular pattern: R ≥5</td>
</tr>
<tr>
<td>2–5</td>
<td>Mixed pattern: R value is &gt;2 and ≤5</td>
</tr>
<tr>
<td>&lt;2</td>
<td>Cholestatic pattern: R ≤2</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Cholestasis</td>
</tr>
</tbody>
</table>

b. PATTERN OF LIVER INJURY according to R value:

1) ALT level ≥5x the upper limit of normal (ULN)
2) Alkaline phosphatase (ALP) level ≥2× ULN (particularly if concomitantly elevated gamma-glutamyl transferase (GGT) in the absence of bone disease) or
3) ALT level ≥3× ULN and simultaneous total bilirubin (TB) level >2× ULN

In patients with abnormal baseline liver blood tests, ULN is replaced by the mean baseline value obtained prior to the exposure to the suspect chemical, and the increases in ALT, ALP and TB should be proportionate to this modified baseline.

Isolated increases in GGT activity are not a marker of cellular damage, rather indicating enzyme induction. It is important to assess whether this liver parameter could be used in occupational medicine as a sensitive early indicator of biological change after exposure to toxicants, once alcohol consumption has been discarded as a causative factor.

The definitions used here refer to an acute hepatic reaction in people exposed to hepatotoxins; the difficulty remains how to define chronic liver disease induced by (transient) exposure to occupational chemicals.

Biochemical classification of drug-induced liver injury

The pattern of liver damage is classified according to International Consensus Meeting criteria, which used ALT and ALP activity, expressed as a multiples of the ULN, to determine the ratio (R) of ALT/ALP. Aspartate aminotransferase (AST) can replace ALT when this one is unavailable. Liver injury is termed hepatocellular when R ≥5, cholestatic when R ≤2, and mixed when R is >2 and ≤5. The values used for the classification of liver damage should be those available from blood tests when liver injury is first recognised. Due to the differences in the clearance kinetics of ALT and ALP, there is a tendency for the liver injury pattern to shift to a cholestatic/mixed biochemical signature.

Alternatively, acute liver damage associated with occupational hepatotoxins can be classified based on liver biopsy findings, which can confirm the biochemical classification and also contribute to diagnostic accuracy. While in DILI the correlation...
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between biochemical categorisation and the histological features is fair, \(^{95}\) for OLDs, data on biochemical and histological correlation are lacking. Toxic exposure to drugs or chemicals can mimic virtually the entire spectrum of liver diseases, which applies especially for OLDs that can often present insidiously with atypical phenotypes of toxic liver injury, including steatosis, TASH, fibrosis, cirrhosis, vascular liver disorders and liver cancer. \(^{88}\) In this context, the liver enzyme threshold values mentioned above are not applicable, because there is a poor relationship between the level of aminotransferases (that can even be normal) and the severity of the liver injury. Therefore, the definition of damage in the setting of a prolonged low-level exposure to occupational toxicants necessarily relies on imaging techniques and histopathological findings. Thus, the criteria adopted to define liver injury developed for DILI (mostly in an acute setting) may have a low sensitivity to detect chronic liver damage related to occupational exposure, which nonetheless can lead to significant liver disease in the long term.

**Definition**

Acute liver injury in occupational workers should be classified as hepatocellular, cholestatic and mixed, according to liver biochemistry during the first laboratory assessment at recognition.

**Evidence:** Level 5 (expert opinion)

**Grading severity of chemical-induced liver disease**

An attempt to grade the severity of OLDs in a comprehensive and systematic way has not proven possible due to the lack of robust evidence. The standard classification used to grade idiosyncratic drug-induced acute liver failure may not apply when considering occupational liver injury because of the direct, massive and rapid liver damage induced by the chemical alongside the often simultaneous involvement of other organs. \(^{96}\) Hence, the characteristic delay of 26 weeks between the onset of jaundice and the appearance of encephalopathy, which is typical for idiosyncratic drug-induced acute liver failure, will likely not occur. On the contrary, fulminant liver failure with symptoms appearing 24–48 h after exposure to the chemical, as observed with CCl\(_4\) poisoning, may be the standard for acute exposure to occupational toxicants. \(^{97}\)

In OLD, other organ failures may be the consequence of the direct effect of the chemical but may also arise from multi-organ failure in the setting of severe liver damage. Indeed, only for a few selected chemicals does hepatotoxicity dominate the clinical picture. These include VCM, \(^{13}\) methylene dianiline, \(^{98}\) and dimethylformamide (DMF), the universal solvent. \(^{99}\) Taking into account these limitations, the severity of chemical liver injury may be evaluated using the adapted severity index scale for DILI (Table 4) (adapted from \([4]\) and \([5]\)).

**Recommendation**

- Severity of acute chemical liver injury can be evaluated using the adapted severity index scale designed for DILI.

**Grade D**

**Evidence:** Level 5 (expert opinion)

**Clinical-pathological presentations**

OLD may present with a wide spectrum of histological lesions ranging from hepatocellular, mixed hepatocellular/cholestatic, vascular, TASH, fibrosis, and malignancy, some of which may coexist in the same patient. Importantly, there are no morphological features that are pathognomonic of toxic injury.

OLD results from high accidental exposure or from prolonged low-level exposures. The former is relatively uncommon and is easily recognised clinically, whereas the latter is more frequent but often overlooked because of the insidious onset, asymptomatic nature, confounding by concurrent conditions and because liver biochemistry may be unremarkable. In addition, specific tests of toxicity are not available, histopathology may not be revealing and the assessment of internal dosing of chemicals is almost always not decisive. Consequently, the long-term effects of low-level exposure on chronic liver disease and liver cancer remain a concern.

On the other hand, whereas there is no evidence to suggest that a transient exposure to occupational chemical hepatotoxins may lead to a chronic liver disease, it might occur, as has been the case for very specific drugs. Indeed, short term use of ebrotidine, an H2 receptor antagonist withdrawn from the market in Spain because of hepatotoxicity, led to cirrhosis rapidly after initial presentation with acute hepatocellular injury. \(^{100}\) Interestingly, ebrotidine has in its chemical structure a bromo-benzene ring \(^{101}\) and the brominated benzenes have been related to hepatotoxicity in experimental studies. \(^{102}\)

Given these circumstances a classification according to clinical presentation is more appropriate.

**Table 4. Category severity description**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Grade mild:</td>
<td>Elevated alanine aminotransferase/ alkaline phosphatase (ALT/ALP) concentration reaching criteria for liver injury* but bilirubin concentration &lt;2 upper limit of normality (ULN)</td>
</tr>
<tr>
<td>2. Grade moderate:</td>
<td>Elevated ALT/ALP concentration reaching criteria* for liver injury and bilirubin concentration ≥2× ULN, or symptomatic hepatitis</td>
</tr>
<tr>
<td>3. Grade severe:</td>
<td>Elevated ALT/ALP concentration reaching criteria for liver injury, bilirubin concentration ≥2× ULN, and one of the following:</td>
</tr>
<tr>
<td></td>
<td>- International normalized ratio ≥1.5</td>
</tr>
<tr>
<td></td>
<td>- Ascites and/or encephalopathy, and absence of underlying cirrhosis</td>
</tr>
<tr>
<td></td>
<td>- Other organ failure considered to be due to occupational liver injury or to the toxic exposure</td>
</tr>
<tr>
<td>4. Grade fatal or liver transplantation:</td>
<td>Death or transplantation due to liver injury</td>
</tr>
</tbody>
</table>

*Category adapted from references 4 and 5.

*Criteria for liver injury are defined in Table 3.

The international normalized ratio (INR) or standardized prothrombin time.
Acute liver injury

Acute hepatitis due to extensive exposure to a toxic agent may result from inhalation (the most important portal of entry), percutaneous absorption or accidental ingestion.

Hepatocellular necrosis

Almost all forms of acute environmental hepatic injury in humans involve the hepatic parenchyma and produce hepatocellular jaundice. Hepatocyte cytolysis and the resulting hepatocellular necrosis characterise most of these acute effects, though in some cases histopathological findings show peculiar features (Table 1). In some instances, hepatocellular damage may present with accompanying hypersensitivity features. Indeed, hepatitis associated with generalised skin disorders has been reported in workers from China and Asia who have been exposed to TCE. Inclusions of copper in lungs and liver were detected in vineyard sprayers and liver histology showed diffuse proliferation of Kupffer cells, sarcoid-like granulomas and atypical proliferation of sinusoidal lining cells. However, it should be noted that acute hepatic injury in the setting of systemic toxicity can be overlooked, as the liver injury may be less significant, in comparison to prominent extrahepatic clinical manifestations of toxicity such as renal failure, skin or pulmonary toxicity.

Acute cholestasis/mixed injury

Hepatocellular necrosis with cholestatic lesions is produced by methylenedianiline and the toxic herbicide paraquat.

Microvesicular steatosis

Microvacuolar steatosis, characterised by the presence of foamy changes in the hepatocyte cytoplasm which is composed of tiny fat droplets with a preserved centrally located nucleus, has been reported upon exposure to dimethylformamide.

Chronic liver injury

Toxicant-associated steatohepatitis

Fatty liver has been related to the occupational exposure to organic solvents. TASH has been described in highly exposed VCM workers. It is a severe form of fatty liver characterised by steatosis, inflammatory infiltrates, ballooning hepatocytes and in some cases fibrosis and cirrhosis, and then is characterised by steatosis, inflammatory infiltrates, ballooning hepato- 
cellular changes in the hepatocyte cytoplasm which is composed of tiny fat droplets with a preserved centrally located nucleus, has been reported upon exposure to dimethylformamide.

Peliosis.

Peliosis, defined by large blood-filled cavities not lined by endothelial cells, results from damage to sinusoidal cells. Marked sinusoidal dilatation is often concomitantly observed.

Porto-sinusoidal vascular disease (previously known as hepatoporal portal hypertension). Porto-sinusoidal vascular disease, a cause of “idiopathic/non-cirrhotic portal hypertension”, is characterised by portal vein obliteration associated with progressive periporal fibrosis. It can result from long exposure to VCM and in vineyards to sprays containing copper sulphate and lime. It seems to be a precursor lesion of angiosarcoma.

Liver malignancies

Primary liver malignancies may develop from epithelial (HCC or biliary/cholangiocarcinoma) or mesenchymal (endothelial/angiosarcoma, vascular/leiomyosarcoma) cells. The most recognised association between toxicants and primary liver malignancies is VCM and angiosarcoma.

Angiosarcoma. Angiosarcomas are high grade tumours that grow rapidly and may lead to hepatomegaly and jaundice. Indeed, angiosarcoma has a very poor prognosis as it is diagnosed at a symptomatic phase, advanced and not resectable or transplantable. At macroscopy, angiosarcomas are often large haemorrhagic nodules, ill-defined, with variably solid and cystic areas. Histologically, the tumour is highly cellular and composed of atypical endothelial cells, elongated or with epithelioid appearance. Different growth patterns may be observed: sinusoidal, solid, papillary, cavernous and anastomosing types. Invasion of hepatic or portal veins is frequent. Specific genomic alterations are observed, including amplification of genes MYC and FLT4.
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Epithelioid haemangiendothelioma. Epithelioid haemangiendothelioma (EHE) of the liver is a recently recognised and uncommon neoplasm of vascular origin. Celin et al., described the first case occurring after close contact with VCM. The patient developed serious portal hypertension with bleeding varices, which required liver transplantation. The patient died 20 months later from variceal haemorrhage and encephalopathy due to local tumour recurrence with portal thrombosis.127

Hepatocellular carcinoma. HCC developed in the setting of OLD does not present any specific morphological features. A distinct case of sequential occurrences of HCC and angiosarcoma of the liver was recently reported in a VCM-exposed worker without cirrhosis and any known risk factor for chronic liver disease.128 Besides, a KRAS G12D point mutation, which is considered to be characteristic of VCM-induced angiosarcoma, was present. Back in 1983, Evans et al. also identified concurrent and sequential angiosarcoma and HCC in 5 VCM workers.129

Diagnosis

Diagnosis relies on a high level of suspicion. A stepwise algorithm approach to OLD diagnosis is depicted in Fig. 1. Thus, in order to establish causality, a coherent synthesis is required between the characteristics of the patient’s disease (phenotype), the exclusion of more common liver disorders, the collection of a thorough occupational history, the presence of hepatotoxic chemicals within an industrial process and their known capability to cause that disease along with the intensity and length of exposures experienced by the workers.

The report of 3 different recurrent acute liver injury episodes, occurring after inadvertent re-exposure to organic solvents at work, highlights the importance of considering OLDs despite their rarity in the differential diagnosis of toxic hepatitis, in order to reach an accurate diagnosis.130 In the EU, the diagnosis of OLD, as well as any other occupational liver disease, relies heavily upon the expertise of certified occupational physicians, those professionals who are responsible for the health surveillance of workers. All workers exposed to (hepatotoxic) chemicals in the EU should follow preventive measures and undergo periodical medical surveillance by a designated occupational physician. His/her tasks include the assessment of chemical exposure by environmental and/or biological monitoring, workplace visits, information to the workers and other preventive measures. Therefore, the occupational physician has a key role (and responsibility) in putting together the specific clinical and exposure information available to other professionals involved in the prevention, detection and management of OLD and interpreting the evidence provided by the rest of the team.

Recommendation

- The diagnosis of OLD should rely on the judgment of an expert occupational physician. The assessment of OLD may be improved, on a case by case basis, by input from a multidisciplinary team including hepatologists, pathologists, toxicologists, and epidemiologists. Grade D Evidence: Level 5 (expert opinion)

Collecting the occupational history

OLDs very rarely display pathognomonic signs and, because of the multifactorial causality of disease, the physician should try to assess the relevance of occupational components in an all-encompassing approach. Taking an occupational history represents a key step in the clinical assessment of suspected OLD. Thus, in addition to focusing on the patient’s symptoms, the work environment must be explored, bearing in mind that occupational exposure occurs most commonly by inhalation and through the skin. The list of information to be obtained from the patient/worker is detailed in Box 2.

In conclusion, collecting all relevant information about the occupation and associated environment is challenging and often requires a multidisciplinary approach that involves occupational medicine physicians and industrial hygienists. The expertise of toxicologists and epidemiologists may also be needed, given the discrepancy between a large number of chemicals that cause liver toxicity experimentally, with little or no evidence in humans131 (Box 3).
ogy underlying this damage. In essence, there are no long-
of liver damage, they do not offer any insight into the aetiol-
and, although they may be used for classification of the type
or, more recently, miRNAs, merely represent liver damage
lined before, liver injury markers such as ALT, AST and GGT
is the unequivocal demonstration of this exposure. As out-

Box 2. Critical information to be obtained from the patient with a
suspicion of occupational liver disease.

1. A chronological summary of all work activities and their duration.
2. A detailed description of the work place, of the job and of a typical working
day.
3. An inventory of all chemicals that are present and how are used.
   Sometimes this information can be obtained from the management.
4. Details of any measures to limit chemical exposure such as: work place
   ventilation and the nature protective measures that are taken (require-
   ment to wear special clothing and gloves, the use of masks, goggles and
   other devices).
5. Enquiring if programs of industrial hygiene, biological monitoring and
   medical surveillance are or have been in place and retrieve the result, if
   necessary, keeping in mind however that compliance with occupational
   exposure limits do not necessarily protect all workers from adverse
   effects.
6. Enquire as to whether coworkers have similar symptoms and signs to
   those of a patient with suspected occupational liver disease. This may
   involve questioning and even examining coworkers. If several cases
   come to light, it may be possible to demonstrate an exposure-response
   relationship.
7. Enquire if compensation procedures have been undertaken and results
   are available.
8. Exposures to chemicals other than those present at work places,
   associated for instance with environmental air pollution, hobbies,
   recreational habits and others should be ruled out.

Box 3. The assessment of occupational liver disease may be improved, on
a case by case basis, by input from a multidisciplinary team encompassing.

- Occupational physicians
- Hepatologists
- Pathologists
- Toxicologists
- Epidemiologists

Assessment of exposure
An inherent difficulty when assessing exposure to chemicals is
the unequivocal demonstration of this exposure. As out-
lined before, liver injury markers such as ALT, AST and GGT
or, more recently, miRNAs, merely represent liver damage
and, although they may be used for classification of the type
of liver damage, they do not offer any insight into the aetiol-
ogy underlying this damage. In essence, there are no long-
term biomarkers that can lead to identification of historical
exposure (i.e. exposure that took place (many) years ago) to
a potential hazardous chemical. Exposure data may, however,
be available and be consulted retrospectively. Monitoring sys-
tems at the workplace is one way to deduce exposure data.
These data could be used to consult workplace exposure limit
databases, such as those from National lists of occupational
limit values (OEL) from EU member states, including Germany
(DFG-MAK Commission), The Netherlands (DECOS), and
France (ANSES), and also from other sources such as the Sci-
cient Committee on Occupational Exposure Limits
(SCOEL), the Occupational Safety and Health Administration
(OSHA), the National Institute of Safety and Health (NIOSH) or
the American Conference of Governmental Industrial Hygien-
ists (ACGIH). Also, data from biomonitoring may be available.
Such data are superior to those obtained from workplace
monitoring systems, as they allow a personalised view of
the exposure. Moreover, in instances where the exposure is
relatively recent (during the past months) or still ongoing,
biomonitoring could be applied to objectively document the
exposure and, based upon quantitative assessments, even
make statements about the extent of exposure.

Urine and blood are the most commonly used biological
matrices for biomonitoring. However, for both matrices, the
window of detection of the toxicants themselves or their
metabolites is quite limited (typically maximally in the range
of days). For a more extended historical window, segmental
hair analysis could be used or, alternatively, adducts in blood
could be monitored. Many of the toxicants listed in
Table 1 will be converted to reactive intermediates in the
liver, which will form covalent adducts with macromolecules
such as DNA and proteins. As both haemoglobin and albumin
are highly abundant proteins, many groups have focused on
adducts with these proteins to document exposure to tox-
icants, even when these toxicants or their metabolites are no
longer detectable in blood or urine. Adducts with haemoglo-
bin are detectable up to >100 days following exposure, as
their disappearance is linked to the lifespan of red blood cells,
which is about 4 months. When the timing of the exposure is
known, it is even possible to perform a back-calculation to
derive the adduct concentration right after the exposure took
place (in case of acute exposure). This gives an idea about the
extent of exposure, compared to the background exposure,
typically assessed in a reference population. Yet, it should
be remarked that there is not necessarily a link between
the level of exposure and the extent of damage, as this will
be compound dependent. Although the markers that can be
assessed this way are highly selective, there are still con-
founders. For example, smoking results in elevated
levels of several albumin and haemoglobin adducts, rendering
it impossible to distinguish moderate exposure to certain tox-
icants from the contribution by smoking. Although
adduct monitoring has already successfully been applied for
a number of compounds listed in Table 1, this approach has
not yet been widely applied for assessing (the absence or
extent of) occupational exposure. The occupational
historical and, when available, the result of workplace
monitoring and biomonitoring, are crucial for formulating a
presumptive diagnosis. It is occasionally necessary to remove
the patient from exposure to the suspected workplace toxic
substance to establish the workplace relationship.

Workup for alternative aetiologies

Laboratory tests
A comprehensive liver aetiology screen should be undertaken,
including evaluation of viral serology (hepatitis A-E), liver
autoantibodies and serum immunoglobulins, ferritin and transf-
ferrin saturation, alpha-1-anti-trypsin levels and ceruloplasmin
(depending on age).
Imaging
Imaging investigations will be determined by the clinical presentation and nature of likely toxin exposure. In many instances, patients will have an initial abdominal ultrasound but may require additional computed tomography (CT) or magnetic resonance imaging (MRI) scanning to delineate the nature of lesions and examine the biliary system in more detail. Indeed, routine abdominal ultrasound along with evaluation of liver fibrosis using transient elastography are advisable in all cases.

Non-invasive diagnosis of liver disease
Non-invasive markers like transient elastography, Fib-4 (Fibrosis 4) and albumin to platelet ratio index (APRI) have been applied to identify and stage liver diseases across multiple aetiologies.\textsuperscript{141} In the setting of liver injury associated with occupational exposure, these tests might help i) Identify sub-clinical hepatic injury not accompanied by symptoms and/or abnormalities of serum liver blood tests, ii) Stage the severity of overt chronic liver disease and, iii) Evaluate resolution of acute liver injury, chronicity suspected after 12 months of persistent alteration (as in DILI\textsuperscript{4}). Whilst the majority of non-invasive tests were conceived as markers of liver fibrosis, increasingly there are data to suggest they may provide information on necro-inflammation and degeneration of liver cells.\textsuperscript{141}

While workers exposed to toxicants may develop a variety of histopathological lesions in the liver, TASH mimics histopathological changes observed in NASH. This is a major challenge, as NASH is emerging as an epidemic across all age strata worldwide, therefore making the characterisation of TASH extremely difficult.\textsuperscript{110,115} Indeed, an individual with liver disease must be considered with TASH on the differential diagnosis.\textsuperscript{141} Histopathological lesions in the liver, TASH mimics histopathological changes observed in NASH. This is a major challenge, as NASH is emerging as an epidemic across all age strata worldwide, therefore making the characterisation of TASH extremely difficult.\textsuperscript{110,115,141} Indeed, an individual with liver disease must be considered with TASH on the differential diagnosis.\textsuperscript{141}

Recommendation
- Staging of OLD can require dynamic evaluation with repeat measurements of liver tests and liver stiffness by transient elastography or serum predictors of fibrosis like Fib-4 and APRI after patient removal from occupational exposure to suspected toxicants. \textbf{Grade D Evidence:} Level 5 (Expert Opinion)

Liver biopsy
Liver biopsy is currently the most reliable approach for diagnosis and staging of liver disease of any aetiology, but it is limited by cost, sampling error and procedure-related morbidity and mortality. In patients with more than 1 risk factor, liver biopsy remains the most robust diagnostic approach to define the cause of underlying liver abnormalities. Workers exposed to potentially hepatotoxic agents may in fact present with comorbidities like overweight, diabetes, arterial hypertension, alcohol abuse, viral hepatitis and medications that cause persistence of liver abnormalities after withdrawal from occupational exposure and may require histological examination of the liver for a definite diagnosis.

When performing a liver biopsy to diagnose a liver mass, sampling of non-tumoral liver is advisable to assess the status of the background liver.

Recommendation
- The relevant health authority and/or compensation agency can be informed of the documented or suspected OLD case. \textbf{Grade D Evidence:} Level 5 (Expert Opinion)

Follow-up
For episodes of acute liver injury with no evidence of liver fibrosis, patients should be followed-up until there is complete resolution of any abnormal liver parameters.

For patients with persistent alterations in liver tests after removal from exposure, one should search for confounding factors or alternative aetiologies and stratify follow-up accordingly to the presence of these coexisting disorders.

Management
Patient management will largely be determined by the nature and severity of the OLD. In acute injury cases the priority is to remove the patient from further exposure whilst establishing the level of liver dysfunction. In the event that the acute liver dysfunction is severe and ongoing, consideration should be given to the appropriate setting within the hospital and need for liver transplantation. This will be determined by the magnitude of liver dysfunction using internationally accepted criteria.\textsuperscript{142}

In the setting of chronic disease, the degree of liver fibrosis will determine management. Advanced fibrosis/cirrhosis will prompt evaluation for the complications of chronic liver disease and also transplantation if there is evidence of significant decompensation.\textsuperscript{142}

There is a need to inform the competent health authority/compensation agency.

Prevention
Successful prevention has markedly reduced the risk of liver diseases to workers, although areas of high risk still exist, particularly in developing countries. Two broad approaches to prevent workers from being affected by liver toxicants are used; primary prevention involves either elimination or alternative aetiologies and stratify follow-up accordingly.

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identification of excessive exposure and early clinical effects in individuals. Thus, prevention is achieved with industrial hygiene techniques, mainly with adherence to exposure limits, and programmes of medical surveillance of exposed workers, aimed at avoiding further damage by removing workers from additional exposure. The decision to temporally or permanently remove the affected workers from the workplace depends on the severity of OLD, working environment and social factors.

As mentioned earlier (section 7.6), the occupational risk is assessed by comparing the measurement of a given environmental exposure with an appropriate exposure limit. These limits may refer to the risk of inhalation or dermal exposures, or both, depending on the chemicals and their uses, and are intended to protect the majority of exposed workers. However, a number of variables influence the exposure of a single worker in addition to a given environmental concentration, including the way materials are handled, the size and ventilation of a specific workplace and the amount of time spent doing specific tasks. Thus, in order to have a reliable assessment of exposure, several environmental measurements are usually needed. While most countries have their own exposure limits, these are broadly comparable with the American ACGIH-derived threshold limit values, which are revised on a regular basis, being the most influential worldwide.

In some circumstances environmental exposures can be controlled at an individual level through the use of biological monitoring as part of medical surveillance. This is based on the analysis of substances or their metabolites in biological fluids, usually blood, urine or breath, which reflects systemic exposures and may provide feedback to ensure the accuracy of environmental assessments. For certain substances biological limit values have also been suggested. Biological monitoring of exposures to hepatotoxic chemicals also includes the assessment of possible consequences by utilising the panel of liver blood tests routinely used in clinical diagnosis. However, these conventional markers may be normal, even in the presence of liver damage and specific tests of toxicity are not available. Raising worker awareness about risks through the provision of information, instruction and training is one of the most important and effective aspects of prevention.

Unmet needs and future research
A step forward in improving safety in the workplace is collecting cohort data from occupational registries including clinical, biochemical and follow-up information in order to obtain incidence figures of hepatotoxicity and trends in (re-)emerging OLD. The importance of reporting associations between environmental exposure and possible liver disease outside registries should also be highlighted.

Another unmet need is the development and quantification of sensitive and specific biomarkers of liver damage caused by toxicants that may help in fine-tuning the differential diagnosis, without the need for histological examination of the liver, and could provide prognostic clues. Advances in the field of biomarkers would allow more effective risk stratification algorithms, while providing mechanistic insights that would help in the development of safe and effective treatments.

Conflict of interest
Please refer to the accompanying ICMJE disclosure forms for further details.

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