

Clinical Practice Guidelines

EASL-EASD-EASO Clinical Practice Guidelines for the Management of Non-Alcoholic Fatty Liver Disease

European Association for the Study of the Liver (EASL)
European Association for the Study of Diabetes (EASD)
European Association for the Study of Obesity (EASO)

Introduction

The Clinical Practice Guidelines (CPG) propose recommendations for the diagnosis, treatment and follow-up of non-alcoholic fatty liver disease (NAFLD) patients and are the product of a joint effort by the European Association for the Study of the Liver (EASL), European Association for the Study of Diabetes (EASD) and European Association for the Study of Obesity (EASO). They update a position statement based on the 2009 EASL Special Conference [1].

The data have been retrieved by an extensive PubMed search up to April 2015. The final statements are graded according to the level of evidence and strength of recommendation, which are adjustable to local regulations and/or team capacities (table 1) [2]. In particular, screening for NAFLD in the population at risk should be in the context of the available resources, considering the burden for the national healthcare systems and the currently limited effective treatments. The document is intended both for practical use and for advancing the research and knowledge of NAFLD in adults, with specific reference to paediatric NAFLD, whenever necessary. The final purpose is to improve patient care and awareness of the importance of NAFLD, and to assist stakeholders in the decision-making process by providing evidence-based data, which also takes into consideration the burden of clinical management for the healthcare system.

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These guidelines were developed by the EASL, EASD and the EASO, and are being published simultaneously in the *Journal of Hepatology*, *Diabetologia* and *Obesity Facts*.

Table 1. Evidence grade used for the EASL-EASD-EASO Clinical Practice Guidelines on NAFLD (adapted from the GRADE system [8])

	Notes	Symbol
<i>Grading of evidence</i>		
High quality	Further research is very unlikely to change our confidence in the estimate effect	A
Moderate quality	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate effect	B
Low or very low quality	Further research is very likely to have an important impact on our confidence in the estimate of effect and may change the estimate effect. Any estimate of effect is uncertain	C
<i>Grading of recommendations</i>		
Strong recommendation warranted	Factors influencing the strength of the recommendation included the quality of the evidence, presumed patient-important outcomes, and cost	1
Weaker recommendation	Variability in preferences and values, or more uncertainty: more likely a weak recommendation is warranted Recommendation is made with less certainty; higher cost or resource consumption	2

Definition

NAFLD is characterised by excessive hepatic fat accumulation, associated with insulin resistance (IR), and defined by the presence of steatosis in >5% of hepatocytes according to histological analysis or by the proton density fat fraction (PDFF, providing a rough estimation of the volume fraction of fatty material in the liver) >5.6% assessed by proton magnetic resonance spectroscopy (¹H-MRS) or quantitative fat/water selective magnetic resonance imaging (MRI). NAFLD includes two pathologically distinct conditions with different prognoses: non-alcoholic fatty liver (NAFL) and non-alcoholic steatohepatitis (NASH); the latter covers a wide spectrum of disease severity, including fibrosis, cirrhosis and hepatocellular carcinoma (HCC) (table 2).

The diagnosis of NAFLD requires exclusion of both secondary causes and a daily alcohol consumption ≥30 g for men and 20 g for women [1]. The relationship between alcohol and liver injury depends on several cofactors (type of alcoholic beverage, drinking patterns, duration of exposure, individual/genetic susceptibility), rendering simple quantitative thresholds at least partly arbitrary. Specifically, patients consuming moderate amounts of alcohol may be still predisposed to NAFLD if they have metabolic risk factors. Of note, the overall impact of metabolic risk factors on the occurrence of steatosis appears to be higher than that of alcohol in these patients [3]. The definitive diagnosis of NASH requires a liver biopsy.

Recommendations

- Patients with IR and/or metabolic risk factors (i.e., obesity or metabolic syndrome (MetS)) should undergo diagnostic procedures for the diagnosis of NAFLD, which relies on the demonstration of excessive liver fat (A1)

Table 2. The spectrum of NAFLD and concurrent diseases

Disease	Subclassification	Most common concurrent diseases
NAFLD ^a	NAFL	Alcoholic fatty liver disease (AFLD) ^b
	Pure steatosis	Drug-induced fatty liver disease ^b
	Steatosis and mild lobular inflammation	HCV-associated fatty liver (genotype 3) ^b
	NASH	Others ^b
	Early NASH: no or mild (F0–F1) fibrosis	Haemochromatosis
	Fibrotic NASH: significant (≥F2) or	Autoimmune hepatitis
	advanced (≥F3, bridging) fibrosis	Coeliac disease
	NASH-cirrhosis (F4)	Wilson's disease
	HCC ^c	A/hypo-betalipoproteinaemia, lipodystrophy
		Hypopituitarism, hypothyroidism
		Starvation, parenteral nutrition
		Inborn errors of metabolism (Wolman disease (lysosomal acid lipase deficiency))

^a Also called primary NAFLD and associated with metabolic risk factors/components of metabolic syndrome:

1. Waist circumference ≥94/≥80 cm for Euroid men/women
2. Arterial pressure ≥130/85 mm Hg or treated for hypertension
3. Fasting glucose ≥100 mg/dl (5.6 mmol/l) or treated for T2DM
4. Serum triacylglycerol >150 mg/dl (>1.7 mmol/l)
5. HDL-cholesterol <40/50 mg/dl for men/women (<1.0/<1.3 mmol/l).

^bAlso called secondary NAFLD. Note that primary and secondary NAFLD may coexist in individual patients. Also NAFLD and AFLD may coexist in subjects with metabolic risk factors and drinking habits above safe limits.

^cCan occur in the absence of cirrhosis and histological evidence of NASH, but with metabolic risk factors suggestive of 'burned-out' NASH.

- Individuals with steatosis should be screened for secondary causes of NAFLD, including a careful assessment of alcohol intake. The interaction between moderate amounts of alcohol and metabolic factors in fatty liver should always be considered (A1)
- Other chronic liver diseases, that may coexist with NAFLD, should be identified as this might result in more severe liver injury (B1)

Prevalence and Incidence

NAFLD is the most common liver disorder in Western countries, affecting 17–46% of adults, with differences according to the diagnostic method, age, sex and ethnicity [4]. It parallels the prevalence of MetS and its components, which also increases the risk of more advanced disease, both in adults and in children. NAFLD is also present in 7% of normal-weight (lean) persons [5], more frequently in females, at a younger age and with normal liver enzymes. Their liver disease may nonetheless be progressive [6].

NAFLD incidence has rarely been measured. It was 20–86/1,000 person-years based on elevated liver enzymes and/or on ultrasound (US), and 34/1,000 per year by ¹H-MRS [7].

The need for NAFLD screening in the community has been questioned given the high direct and indirect costs of testing, the low predictive value of non-invasive tests, the risks of liver biopsy and the lack of effective treatments [8]. However, the progressive form of NAFLD

(i.e. NASH), particularly when associated with advanced fibrosis, should be identified in patients at risk (age > 50 years, type 2 diabetes mellitus (T2DM) or MetS), because of its prognostic implications. Validated cost-utility studies on extensive screening programmes are eagerly awaited. Similarly, although familial clustering occurs, family screening is not generally advisable, with the exception of cases with defined inherited diseases (e.g. lysosomal acid lipase deficiency).

Recommendations

- All individuals with steatosis should be screened for features of MetS, independent of liver enzymes. All individuals with persistently abnormal liver enzymes should be screened for NAFLD, because NAFLD is the main reason for unexpectedly elevated liver enzymes (A1)
- In subjects with features of MetS, screening for NAFLD by liver enzymes and/or ultrasound should be part of routine work-up. In high risk individuals (age > 50 years, T2DM, MetS) case finding of advanced disease (i.e. NASH with fibrosis) is advisable (A2)

Pathogenesis: Lifestyle and Genes

A high-calorie diet, excess (saturated) fats, refined carbohydrates, sugar-sweetened beverages, a high fructose intake and a Western diet [9] have all been associated with weight gain and obesity, and more recently with NAFLD. High fructose consumption may increase the risk of NASH and advanced fibrosis, although the association may be confounded by excess calorie intake or by unhealthy lifestyles and sedentary behaviour [10], which are more common in NAFLD [11].

Recommendations

- Unhealthy lifestyles play a role in the development and progression of NAFLD. The assessment of dietary and physical activity habits is part of a comprehensive NAFLD screening (A1)

Several genetic modifiers of NAFLD have been identified [12], but a minority has been robustly validated (supplementary table 1; available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=443344>). The best-characterised genetic association is with *PNPLA3*, initially identified from genome-wide association studies and confirmed in multiple cohorts and ethnicities as a modifier of NAFLD severity across the entire histological spectrum [13, 14]. Recently, the *TM6SF2* gene has been reported as another disease modifier [15, 16] and may have clinical utility assisting risk stratification for liver-related vs. cardiovascular morbidity.

The *PNPLA3* rs738409 variant also confers susceptibility and affects the histological pattern of NAFLD and fibrosis in obese children and adolescents [17]. A NASH risk score based on four polymorphisms has been validated in obese children with increased liver enzymes [18].

Recommendations

- Carriers of the *PNPLA3* I148M and the *TM6SF2* E167K variants have a higher liver fat content and increased risk of NASH. NAFLD due to these variants is not systematically associated with features of insulin resistance. Genotyping may be considered in selected patients and clinical studies but is not recommended routinely (B2)

Liver Biopsy

Liver biopsy is essential for the diagnosis of NASH and is the only procedure that reliably differentiates NAFL from NASH, despite limitations due to sampling variability [19].

NAFL encompasses: a) steatosis alone, b) steatosis with lobular or portal inflammation, without ballooning, and c) steatosis with ballooning but without inflammation [20]. The diagnosis of NASH requires the joint presence of steatosis, ballooning and lobular inflammation [20–22]. Other histological features can be seen in NASH, but are not necessary for the diagnosis: portal inflammation, polymorphonuclear infiltrates, Mallory-Denk bodies, apoptotic bodies, clear vacuolated nuclei, microvacuolar steatosis and megamitochondria. Perisinusoidal fibrosis is also frequent, but not part of the diagnostic criteria; the term ‘borderline’ NASH is confusing, unnecessary and should be abandoned. The prospectively designed FLIP algorithm increases observer agreement and precisely defines the grading of ballooning [22]. ‘Burned-out NASH’ describes regression of advanced disease (steatosis, inflammation or ballooning) in patients exposed to metabolic risk factors.

The NAFLD Activity Score (NAS) scoring system should not be used for the diagnosis of NASH but rather for the evaluation of disease severity, once the diagnosis has been established by the overall pathological assessment. Although NAS is correlated with aminotransferase and homeostasis model assessment of insulin resistance (HOMA-IR) [23], they have a low prognostic value [24]. The steatosis, activity and fibrosis (SAF) score [22] is an alternative with good reproducibility and provides a more accurate and comprehensive description. Fibrosis staging relies on the Kleiner classification [21] (used in a simplified pattern in SAF) [22].

In children, NASH displays many of the features observed in adults, even though the distribution of lesions may be different. Portal inflammation is a frequent feature, but can also be seen in adults with more severe disease [25]. Hepatocellular ballooning and Mallory-Denk bodies are only sporadically observed in paediatric NASH, and portal-based chronic inflammation is predominant [21]. Based on the distinctive histological pattern, a specific histological score (Paediatric NAFLD Histological Score – PNHS) has been validated for a better classification of children with/without NASH [26].

Non-Invasive Assessment

Non-invasive markers should aim to: i) in primary care settings, identify the risk of NAFLD among individuals with increased metabolic risk; ii) in secondary and tertiary care settings, identify those with worse prognosis, e.g. severe NASH; iii) monitor disease progression; iv) predict response to therapeutic interventions. Achieving these objectives could reduce the need for liver biopsy.

Steatosis

Rationale: Steatosis should be documented whenever NAFLD is suspected as the primary disease or as a coexisting condition. It also predicts future diabetes mellitus, cardiovascular events and arterial hypertension. In clinical practice, quantification of fat content is not of interest, except as a surrogate of treatment efficacy, and is therefore not generally recommended.

In individual patients, especially in tertiary care centres, steatosis should be identified by imaging, preferably US, because it is more widely available and cheaper than the gold standard,

MRI (supplementary table 2; available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=443344>). US has limited sensitivity and does not reliably detect steatosis when <20% [27, 28] or in individuals with high BMI (>40 kg/m²) [29]. Despite observer dependency, US (or computed tomography (CT) or MRI) robustly diagnoses moderate and severe steatosis and provides additional hepatobiliary information, hence it should be performed as a first-line diagnostic test. However, for larger-scale screening studies, serum biomarkers are preferred, as availability and cost of imaging substantially impact feasibility (supplementary table 3; available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=443344>). The best-validated steatosis scores are the fatty liver index (FLI), the SteatoTest[®] and the NAFLD liver fat score; they have all been externally validated in the general population or in grade 3 obese persons and variably predict metabolic, hepatic and cardiovascular outcomes/mortality. These scores are associated with IR and reliably predict the presence, not the severity, of steatosis [30]. Another imaging technique, the controlled attenuation parameter (CAP) can diagnose steatosis, but has a limited ability to discriminate histological grades and has never been compared with ¹H-MRS-measured steatosis. Also, the data from studies comparing CAP with US are inconclusive. Thus more data are needed to define the role of CAP.

Recommendations

- US is the preferred first-line diagnostic procedure for imaging of NAFLD, as it provides additional diagnostic information (A1)
- Whenever imaging tools are not available or feasible (e.g., large epidemiological studies), serum biomarkers and scores are an acceptable alternative for the diagnosis of steatosis (B2)
- A quantitative estimation of liver fat can only be obtained by ¹H-MRS. This technique is of value in clinical trials and experimental studies, but is expensive and not recommended in the clinical setting (A1)

Steatohepatitis, NASH

Rationale: The diagnosis of NASH provides important prognostic information and indicates an increased risk of fibrosis progression, cirrhosis and possibly hepatic comorbidities (HCC). It may also prompt a closer follow-up and possibly a greater need for more intensive therapy.

Clinical, biochemical or imaging measures cannot distinguish NASH from steatosis [31, 32]. Cytokeratin-18 fragments (CK-18), which are generated during cell death (M65 fragments) or apoptosis (M30 fragments), have modest accuracy for the diagnosis of NASH (66% sensitivity, 82% specificity) [33, 34]. CK-18 changes parallel histological improvement but do not perform better than alanine transaminase (ALT) in identifying histological responders [35]. To date, non-invasive tests are not validated for the diagnosis of NASH.

Recommendations

- NASH has to be diagnosed by a liver biopsy showing steatosis, hepatocyte ballooning and lobular inflammation (A1)

Fibrosis

Rationale: Fibrosis is the most important prognostic factor in NAFLD and is correlated with liver-related outcomes and mortality [24]. The presence of advanced fibrosis identifies

patients in need of in-depth hepatological investigation, including, on a case-by-case basis, confirmatory biopsy and intensive therapies. Monitoring of fibrosis progression is also necessary at variable time intervals.

Many serum markers have shown acceptable diagnostic accuracy as defined by an area under the receiver operating characteristic curve (AUROC) >0.8 (supplementary table 3; available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=443344>) [32]. NAFLD fibrosis score (NFS) and fibrosis 4 calculator (FIB-4) have been externally validated in ethnically different NAFLD populations, with consistent results. NFS, FIB-4, Enhanced Liver Fibrosis (ELF) and FibroTest® predict overall mortality, cardiovascular mortality and liver-related mortality. NFS predicts incident diabetes, and changes in NFS are associated with mortality. The tests perform best at distinguishing advanced ($\geq$ F3) vs. non-advanced fibrosis but not significant ($\geq$ F2) or any ($\geq$ F1) fibrosis vs. no fibrosis [36]. Importantly, the negative predictive values (NPVs) for excluding advanced fibrosis are higher than the corresponding positive predictive values (PPVs) [36, 37]; therefore, non-invasive tests may be confidently used for first-line risk stratification to exclude severe disease. However, predictive values depend on prevalence rates and most of these studies have been conducted in tertiary centres where the pre-test probability of advanced fibrosis is higher than in the community.

Among imaging techniques, transient elastography performs better for cirrhosis (F4) than for advanced fibrosis (F3). Elastography has a higher rate of false-positive than false-negative results and higher NPV than PPV [38], hence the ability to diagnose bridging fibrosis or cirrhosis is insufficient for clinical decision-making. The main shortcoming of transient elastography is unreliable results in the presence of high BMI and/or thoracic fold thickness. In a large, unselected, European series, up to 20% of examinations had unreliable results [39], mainly in obese NAFLD [38]. The XL probe should be used in these patients to reduce the failure rate, which remains high (35%) [40].

There is no consensus on thresholds or strategies for use in clinical practice when trying to avoid liver biopsy [32]. Some data suggest that the combination of elastography and serum markers performs better than either method alone [41]. Importantly, longitudinal data correlating changes in histological severity and in non-invasive measurements are urgently needed.

Recommendations

- Biomarkers and scores of fibrosis, as well as transient elastography, are acceptable non-invasive procedures for the identification of cases at low risk of advanced fibrosis/cirrhosis (A2). The combination of biomarkers/scores and transient elastography might confer additional diagnostic accuracy and might save a number of diagnostic liver biopsies (B2)
- Monitoring of fibrosis progression in clinical practice may rely on a combination of biomarkers/scores and transient elastography, although this strategy requires validation (C2)
- The identification of advanced fibrosis or cirrhosis by serum biomarkers/scores and/or elastography is less accurate and needs to be confirmed by liver biopsy, according to the clinical context (B2)
- In selected patients at high risk of liver disease progression, monitoring should include a repeat liver biopsy after at least 5-year follow-up (C2)

Non-Invasive Testing in Paediatric NAFLD

The position paper by the European Society for Paediatric Gastroenterology Hepatology and Nutrition (ESPGHAN) Hepatology Committee has recently delineated diagnostic criteria for

paediatric NAFLD [42]. In obese children, NAFLD should always be suspected; elevated amino-transferase levels and liver hyperechogenicity deserve further evaluation and the exclusion of other causes of liver disease. Due to the poor sensitivity of these tests in overweight/obese children, non-invasive markers and imaging techniques are the first diagnostic step [43].

Recommendations

- In children, predictors of fibrosis, including elastometry, acoustic radiation force impulse (ARFI) imaging and serum biomarkers might help reduce the number of biopsies (B2)

Common Metabolic Disorders Related to NAFLD

NAFLD is tightly associated with IR not only in the liver but also in muscle and adipose tissues [44], and also with MetS, defined as the cluster of any three of the following five features associated with IR: impaired fasting glucose (IFG) or T2DM, hypertriglyceridaemia, low high-density lipoprotein(HDL)-cholesterol (gender-adjusted), increased waist circumference (ethnicity adjusted) and high blood pressure [45]. As all components of MetS correlate with liver fat content, independently of BMI, the presence of MetS in any given patient should lead to an evaluation of the risk of NAFLD, and vice versa the presence of NAFLD should lead to an assessment of all components of MetS.

Hepatic triacylglycerol accumulation is accompanied by abnormal hepatic energy metabolism [46] and impaired insulin-mediated suppression of hepatic glucose and very low-density lipoprotein production [47], leading to hyperglycaemia, hypertriglyceridaemia and hyperinsulinaemia. In non-diabetic persons, the product of fasting glucose (in mmol/l) and insulin (in mU/ml), divided by 22.5 (HOMA-IR) can serve as surrogate for IR [48], and is therefore an acceptable alternative to more expensive and time-consuming dynamic testing. Liver disease progression has been associated with persistence or worsening of metabolic abnormalities, including HOMA-IR [49, 50]. However, the validity of HOMA-IR depends on the ability of insulin secretion to adapt to IR, questioning its suitability in overt diabetes. Moreover, the assays for insulin measurements vary widely, and there is no agreement on a threshold defining IR using HOMA-IR.

Recommendations

- HOMA-IR provides a surrogate estimate of IR in persons without diabetes and can therefore be recommended provided proper reference values have been established (A1)
- HOMA-IR is of limited use for NAFLD diagnosis in patients with metabolic risk factors. It could confirm altered insulin sensitivity, thereby favouring a diagnosis of IR-associated NAFLD, in cases of diagnostic uncertainty (e.g. US-defined steatosis with normal body weight) (B2)
- During follow-up, HOMA-IR might help identify patients at risk of NASH or fibrosis progression in selected cases. Improvement of HOMA-IR during weight loss may indicate metabolic improvement that could be beneficial for NAFLD (C2)

Obesity

BMI and waist circumference, a measure of visceral adiposity, are positively related to the presence of NAFLD [51] and predict advanced disease, particularly in the elderly [52]. A large proportion of patients with cryptogenic cirrhosis have a high prevalence of metabolic

risk factors [53], suggesting that in the majority of cases of cryptogenic cirrhosis are ‘burned-out’ NASH. Common comorbidities of obesity, such as T2DM, and sleep apnoea [54], polycystic ovary syndrome and other endocrine disorders (hypogonadism), further drive NAFLD prevalence and severity.

Importantly, patients with BMI <30 kg/m² (or even <25 kg/m²) but with visceral fat accumulation or dysfunctional adipose tissue can exhibit NAFLD with/without abnormal liver enzymes [44, 55]. The currently used concept of ‘metabolically healthy’ obese individuals should be considered with caution, given that they may exhibit gene expression similar to those of metabolically altered obese patients, and may have altered liver tests and adverse health outcomes when longitudinally examined [56, 57].

Recommendations

- Obesity is the major phenotype and risk condition for NAFLD, driven by IR, which also increases the risk of advanced disease (A1)
- Most lean persons with NAFLD display IR and altered body fat distribution even though they have less severe metabolic disturbance than overweight NAFLD. Follow-up is nonetheless required because of possible disease progression (B2)

Diabetes mellitus

T2DM patients are insulin resistant, often obese, dyslipidaemic, display increased liver enzymes [58] and tend to accumulate hepatic fat independently of BMI [59, 60]. The prevalence of NAFLD is also higher in persons at risk of T2DM, defined as a glycosylated haemoglobin A_{1c} (HbA_{1c}) of 5.7–6.4% (38.8–46.4 mmol/mol), IFG (fasting glucose: 100–125 mg/dl (5.55–6.94 mmol/l)) and/or impaired glucose tolerance (IGT; glucose: 140–199 mg/dl (7.77–11.04 mmol/l) at 2 h of the standardised 75 g oral glucose tolerance test (OGTT)). Diabetes risk and T2DM closely associate with the severity of NAFLD, progression to NASH, advanced fibrosis and the development of HCC [4, 61], independently of liver enzymes [6]. Conversely, US-defined NAFLD is associated with a 2- to 5-fold risk of developing T2DM after adjustment for several lifestyle and metabolic confounders [62]. The standardised 75 g OGTT should therefore be performed in persons with increased diabetes risk [63, 64].

Insulin treatment increases body fat, but it does not appear to promote or worsen NAFLD in diabetes [65, 66]. While acute insulin infusion dose-dependently increases liver fat content in T2DM [67], chronic insulin treatment improves adipose tissue IR and therefore reduces NEFA flux and hepatic fat content.

Recommendations

- In persons with NAFLD, screening for diabetes is mandatory, by fasting or random blood glucose or HbA_{1c} (A1) and, if available, by the standardised 75 g OGTT in high-risk groups (B1).
- In patients with T2DM, the presence of NAFLD should be looked for irrespective of liver enzyme levels, since T2DM patients are at high risk of disease progression (A2).

Diagnostic Algorithm and Follow-Up

The incidental discovery of steatosis should lead to comprehensive evaluation of family and personal history of NAFLD-associated diseases and the exclusion of secondary causes of steatosis. Metabolic work-up has to include a careful assessment of all components of MetS

Table 3. Protocol for a comprehensive evaluation of suspected NAFLD patients

Level	Item
Initial	Alcohol intake: <20 g/day (women), <30 g/day (men) Personal and family history of diabetes, hypertension and CVD BMI, waist circumference, change in body weight Hepatitis B/hepatitis C virus infection History of steatosis-associated drugs Liver enzymes (aspartate and alanine transaminases (γ -glutamyl-trans-peptidase)) Fasting blood glucose, HBA _{1c} , OGTT, (fasting insulin (HOMA-IR)) Complete blood count Serum total and HDL-cholesterol, triacylglycerol, uric acid Ultrasonography (if suspected for raised liver enzymes)
Extended*	Ferritin and transferrin saturation Tests for coeliac and thyroid diseases, polycystic ovary syndrome Tests for rare liver diseases (Wilson, autoimmune disease, α 1-antitrypsin deficiency)
*According to a priori probability or clinical evaluation.	

[63]. Similarly, the presence of obesity/T2DM or the incidental finding of raised liver enzymes in patients with metabolic risk factors should prompt non-invasive screening to predict steatosis, NASH and fibrosis (table 3).

Surrogate markers of fibrosis (NFS, FIB-4, ELF or FibroTest) should be calculated for every NAFLD patient, in order to rule out significant fibrosis ($\geq$ F2). If significant fibrosis cannot be ruled out, patients should be referred to a Liver Clinic for transient elastography; if significant fibrosis is confirmed, the final diagnosis should be made by liver biopsy (fig. 1). All cases with diabetes or diabetes risk should be referred to a Diabetes Clinic for optimal management. Those at increased diabetes risk should be included in a structured lifestyle modification programme. Obesity should prompt the inclusion of the patient in a structured weight loss programme and/or referral to an obesity specialist. Finally, all cases should receive comprehensive cardiovascular disease (CVD) work-up.

The optimal follow-up of patients with NAFLD is as yet undetermined. Risk of progression of both the hepatic disease and the underlying metabolic conditions as well as the cost and workload for healthcare providers need to be considered. Monitoring should include routine biochemistry, assessment of comorbidities and non-invasive monitoring of fibrosis. NAFL patients without worsening of metabolic risk factors should be monitored at 2- to 3-year intervals. Patients with NASH and/or fibrosis, should be monitored annually, those with NASH cirrhosis at 6-month intervals. If indicated on a case-by-case basis, liver biopsy could be repeated after 5 years.

Natural History and Complications

Disease Progression

In general, NAFLD is a slowly progressive disease, both in adults and in children, but fibrosis rapidly progresses in 20% of cases [68]. The rate of progression corresponds to 1 fibrosis stage every 14 years in NAFL and every 7 years in NASH, and is doubled by arterial hypertension [68]. NASH is associated with an increased standardised mortality ratio

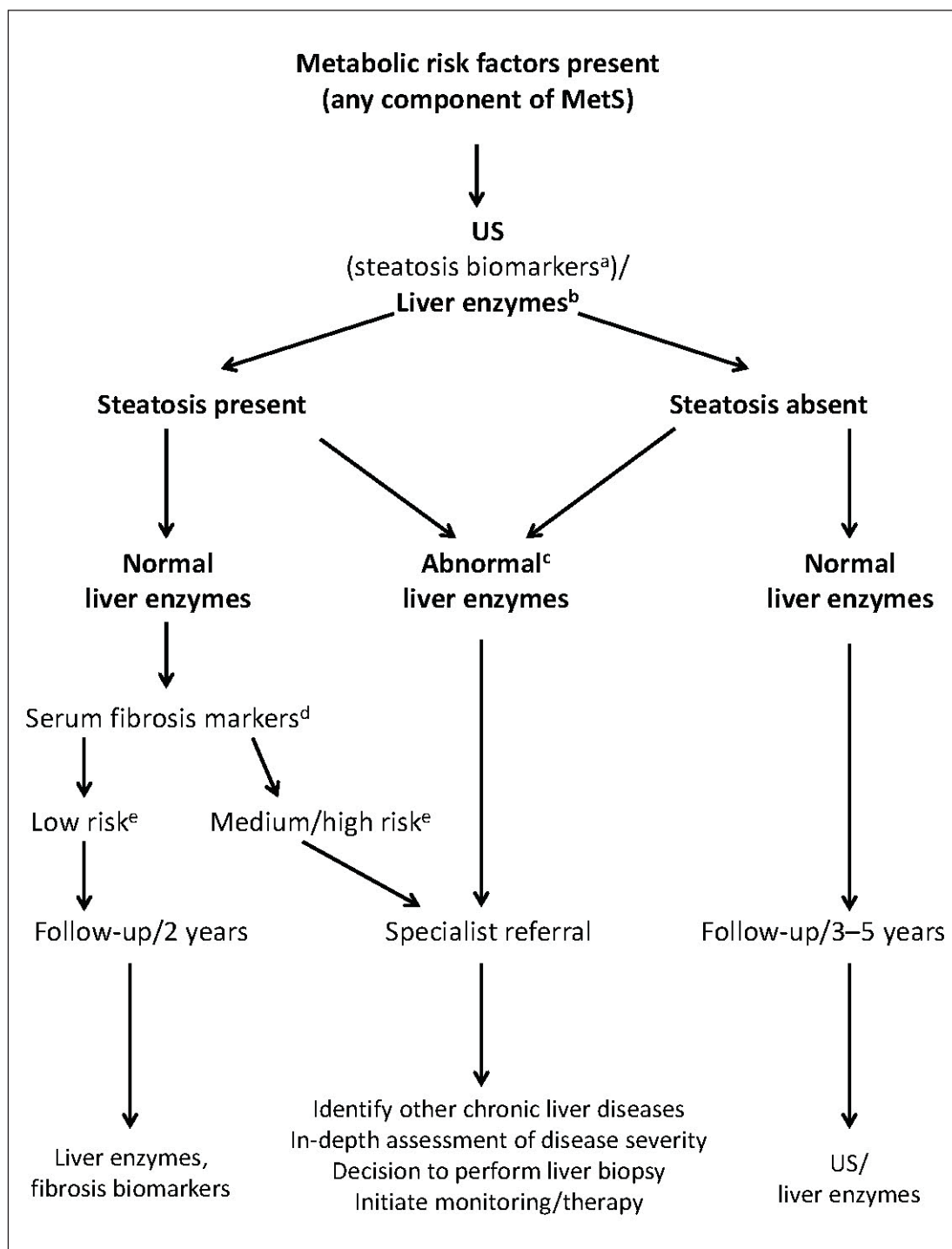


Fig. 1. Diagnostic flow-chart to assess and monitor disease severity in the presence of suspected NAFLD and metabolic risk factors. ^aSteatosis biomarkers: Fatty Liver Index, SteatoTest, NAFLD Fat score (see tables). ^bLiver tests: ALT AST, γ -glutamyltransferase (GGT). ^cAny increase in ALT, AST or γ -glutamyltransferase (GGT). ^dSerum fibrosis markers: NAFLD Fibrosis Score, FIB-4, Commercial tests (FibroTest, FibroMeter, ELF). ^eLow risk: indicative of no/mild fibrosis; medium/high risk: indicative of significant fibrosis or cirrhosis (see tables).

compared with the general population [69], and liver disease is the third most common cause of death after CVD and cancer. US-diagnosed NAFLD is not associated with increased mortality [70], presumably because progression to NASH and fibrosis is rare for steatosis alone [49, 50].

Recommendations

- NASH patients with fibrosis associated with hypertension should receive closer monitoring because of a higher risk of disease progression (B1)

Paediatric NAFLD is of concern because of the potential for severe liver-related complications later in life [8]. NASH-related cirrhosis has been reported as early as 8 years of age [71].

CVD

The prevalence and incidence of CVD is higher in NAFLD than in matched controls and driven by the association between NAFLD and MetS components ([72, 73] (supplementary table 4; available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=443344>). CVD is a more common cause of death than liver disease in NAFLD [73]. In most studies, biochemical markers of atherosclerosis (low HDL-cholesterol, high triacylglycerol) or inflammation (high-sensitive C-reactive protein), and increased levels of procoagulant/prothrombotic factors are more common in NAFLD than in persons without steatosis [73]. Pre-atherogenic lesions such as increased carotid intima-media thickness; coronary artery, abdominal aortic and aortic valve calcifications; endothelial dysfunction and functional unresponsiveness of the artery wall are more prevalent in NAFLD and are, in some studies, correlated with histological severity. Other defects such as echocardiographic and ECG abnormalities and altered cardiac energy metabolism have also been demonstrated [74]. They are largely independent of traditional risk factors, duration of diabetes, glycaemic control, drug treatment and MetS components. In the general population, US-detected steatosis and its surrogate markers (e.g., FLI) are associated with a higher risk of CVD mortality in the long term [75], and the risk increases further in NASH and in advanced fibrosis [73].

The overall consensus is that CVD should be identified in NAFLD regardless of the presence of traditional risk factors. Conversely, NAFLD screening should be performed in persons at high CVD risk. An association between serum γ -glutamyltransferase (GGT) and CVD incidence has been prospectively established, although it is insufficient for devising follow-up protocols. Notably, CVD and metabolic risk factors are also reported in adolescents and children with NAFLD [76].

Recommendations

- Cardiovascular complications frequently dictate the outcome of NAFLD and screening of the cardiovascular system is mandatory in all persons (A1)

HCC

Large-scale epidemiological studies have repeatedly associated obesity and T2DM with the risk of HCC, and the occurrence of HCC has also been reported in NAFLD/cryptogenic cirrhosis. The cumulative incidence of NAFLD-associated HCC (>10-fold higher in T2DM and obesity) varies according to study population (population-based, natural history vs. clinic-

based cohorts with/without fibrosis or cirrhosis) from 7.6% at 5 years in persons with advanced fibrosis or cirrhosis to only 0.25% in a larger series, followed for 5.6 years [77].

At diagnosis, patients with NAFLD-associated HCC are older than those with non-NAFLD HCC, have more extrahepatic comorbidities, but a lower prevalence of cirrhosis (only two-thirds of cases) (supplementary table 5; available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=443344>). NAFLD-related HCC may, however, be diagnosed at more advanced stages, due to less systematic surveillance, and receive less treatment. Conflicting data are reported on survival. At present, NAFLD is the second leading indication for HCC-related transplantation in the USA [78].

The large number of NAFLD cases at risk of HCC makes systematic surveillance largely impracticable. *PNPLA3* rs738409: C>G gene polymorphism has been associated with an increased HCC risk and might provide patient-risk stratification for tailored HCC surveillance in NAFLD, but it is not yet considered cost-effective (supplementary table 1; available at <http://content.karger.com/ProdukteDB/produkte.asp?doi=443344>).

Recommendations

- Although NAFLD is a risk factor for HCC, which may also develop in the pre-cirrhotic stage, and the risk is further increased by the presence of the *PNPLA3* rs738409 C>G polymorphism, no recommendation can be currently made on the timing of surveillance and its cost-effectiveness (B1)

Other Extrahepatic Disorders

Chronic kidney disease (CKD) can be found in 20–50% of NAFLD patients, particularly in biopsy-proven NASH [79]. US-defined NAFLD carries a 1.5- to 2-fold adjusted risk of incident CKD in type 1 diabetes mellitus [80].

NAFLD is also associated with colorectal cancer [81], metabolic bone disease (vitamin D deficiency, osteoporosis) [62, 82] and rare metabolic diseases (lipodystrophies, glycogen storage diseases).

Treatment

Rationale: Successful treatment of NASH should improve outcomes, i.e. decrease NASH-related mortality, reduce progression to cirrhosis or HCC. The resolution of the histological lesions defining NASH is now accepted as a surrogate endpoint, particularly in clinical trials. Only a few properly designed randomised controlled trials (RCTs) are available, with improvement/regression of hepatic necroinflammation and/or fibrosis as primary outcomes [83–105] (table 4).

Diet and Lifestyle Changes

Rationale: Epidemiological evidence suggests a tight relationship between unhealthy lifestyle and NAFLD [106], which makes lifestyle correction mandatory in all patients (table 5). Of note, daily alcohol consumption up to 30 g (men) or 20 g (women) is insufficient to induce alcoholic steatosis and might even be protective against NAFLD, NASH and fibrosis as compared with total abstinence.

Table 4. Randomised controlled trials with histological outcomes in NAFLD

Author, year [ref]	Treatment	Duration	Significant results	Comment
Lindor, 2004 [83]	UDCA 13–15 mg/kg, 70; PL, 74	2 years	Changes in steatosis, inflammation or fibrosis not different between arms	Follow-up biopsies: UDCA, 50; PL, 57. No differences in side-effects between arms
Bugianesi, 2005 [84]	MET 2 g, 55; Vit. E, 28; diet, 27	12 months	Decreased fat, fibrosis and necroinflammation in MET at follow-up	Vit. E and diet combined as control group. Follow-up biopsies only in metformin non-responders
Belfort, 2006 [85]	PIO 45 mg, 29; counselling, 25	6 months	Improved biochemistry and histology (including fibrosis)	4 cases in PIO and 3 in counselling lost to follow-up
Zelber-Sagi, 2006 [86]	ORL 120 mg × 3, 21; PL, 23 (biopsy, 40)	6 months	Larger weight loss and reversal of steatosis in ORL. No effects on fibrosis	Only 11 cases per arm had biopsy at follow-up
Dufour, 2006 [87]	UDCA 12–15 mg + Vit. E 400 IU, 15; UDCA + PL, 18; PL + PL, 15	2 years	Improved composite histological index with combined treatment. No changes in fibrosis	Only 32 cases with an end-of-treatment biopsy
Ratzl, 2008 [88] FLIRT trial	RSG 8 mg, 32; PL, 31	12 months	Improved steatosis, no differences in fibrosis or necroinflammation	10 cases lost to follow-up (RSG, 7; PL 3); weight gain as side-effect of treatment
Aithal, 2008 [89]	PIO 30 mg, 37; PL, 37	12 months	Improved histology (liver injury and fibrosis)	13 patients withdrew; weight gain differences, 3 kg with PIO
Haukeland, 2009 [90]	MET 2.5–3 g, 24; controls, 24	6 months	No differences in CT-assessed steatosis, biochemistry, histology	Per protocol analysis; 4 dropouts in MET
Harrison, 2009 [91]	Vit. E 800 IU + ORL 120 mg × 3, 25; Vit. E, 25	36 weeks	Similar improvement in steatosis, inflammation and activity scores	Only 41 biopsies at follow-up. Weight loss ≥9% associated with improved histology, independent of treatment
Shields, 2009 [92]	MET 0.5–1 g, 9; counselling, 10	12 months	No differences in biochemistry or histology	Per protocol analysis, 3 dropouts in counselling
Promrat, 2010 [93]	CBT, 21; controls, 10	48 weeks	Decreased fat and NAS score	CBT aimed at 7–10 weight loss. Results driven by weight loss
Ratzl, 2010 [94] FLIRT 2 trial	RSG, 53 (RSG-RSG, 25; PL-RSG, 28)	24 months	No further histological improvement beyond one year.	Extension of [88]. Only 40 cases available at follow-up (RSG-RSG, 18; PL-RSG, 22)
Sanyal, 2010 [95] PIVENS trial	NASH (no T2DM) 96 weeks PIO 30 mg, 87; Vit. E, 84; PL, 83	96 weeks	Vit. E better than PL but no better than PIO. Both drugs better than PL on steatosis and lobular inflammation, not fibrosis	PIO failed the primary outcome, but Vit. E better than PL on NASH score. Weight gain was a side-effect of PIO

Table 4 Continued on next page

Table 4. Continued

Author, year [ref]	Treatment	Duration	Significant results	Comment
Leuschner, 2010 [96]	UDCA 23-28 mg/kg, 95; PL, 91	18 months	UDCA better than PL only in lobular inflammation	NAS score only available in 69 (UDCA) and 68 (PL)
Zein, 2011 [97]	PTX 400 mg × 3, 26; PL, 29	12 months	PTX improved NAS score more than 3 dropouts in both groups; no significant improvement in PL. Improved fibrosis (not significant) in PTX	difference in secondary outcomes (liver enzymes, apoptosis, cytokines)
Lavine, 2011 [98] TONIC trial	Paediatric study Vit. E 800 UI, 57; MET 1 g, 57; PL, 58	96 weeks	NAS score improved in all groups. Compared with PL, no benefit was seen with Vit. E or MET for aminotransferases	Histology was only a secondary outcome
Neuschwander-Tetri, 2014 [99] FLINT trial	OCA 25 mg, 141; PL 142 Trial stopped for superiority: OCA, 102; PL, 98	72 weeks	Early discontinuation for efficacy: improved histology (steatosis, lobular inflammation, ballooning, fibrosis) in 45% OCA vs. 21% PL.	Increase in LDL cholesterol and pruritus in 23% of OCA treated cases (sometimes intense, widespread and/or interfering with daily activities)
Valenti, 2014 [100]	NASH with high ferritin or high iron phlebotomy + lifestyle, 21; lifestyle, 17	2 years	NAFLD activity score (primary outcome) significantly improved. Histology was secondary outcome	Only 19 cases underwent follow-up biopsies.
Takeshita, 2014 [101]	EZE 10 mg/day, 17; PL, 15	6 months	Prematurely stopped for EZE adverse events (increased HbA1c). Modest improvement in NAFLD staging and ballooning	Only 16 EZE and 12 PL available for follow-up histology (secondary outcome). Lipid profile and gene expression, suggestive of impaired oxidation of long-chain fatty acids
Sanyal 2014 [102]	EPA-E 1.8 g, 82; EPA-E 2.7 g, 86; PL, 75	12 months	In the 3 arms, 40%, 37%, and 35.9% of cases reached the primary endpoint (NAFLD activity score ≤3, no worsening of fibrosis)	No significant effects on liver enzymes, insulin resistance, adiponectin, keratin 18, high-sensitivity C-reactive protein, or hyaluronic acid
Loomba, 2015 [103] MOZART trial	EZE 10 mg, 25; PL, 25	24 weeks	EZE not better than PL on liver fat (primary outcome, MRI assessment)	No differences in histology or MR-liver stiffness (secondary outcomes)
Argo, 2015 [104]	n-3 PUFA 3 g, 17; PL, 17	1 year	PUFA not better than PL on NAS reduction ≥2 points without fibrosis progression	PUFA led to reduced liver fat by multiple measures, regardless of weight loss
Armstrong, 2015 [105] LEAN programme	LIRA 1.8 mg, 26; PL, 26	48 weeks (extension to 72)	NASH resolution significantly higher with LIRA (39% vs. 9% in PL)	NASH resolution, no worsening of fibrosis as primary outcome (follow-up biopsies available in 23 + 22 cases)

C = Control arm; CBT = cognitive-behaviour therapy; E = experimental arm; EPA = eicosapentanoic acid; EZE = ezetimibe; HbA1c, glycosylated haemoglobin; LIRA = liraglutide; MET = metformin; MR = magnetic resonance; MRI = magnetic resonance imaging; NAS = NAFLD activity score; OCA = obeticholic acid; ORL = orlistat; PIO = pioglitazone; PL = placebo; PTX =, pentoxifylline; PUFA = polyunsaturated fatty acids; RSG = rosiglitazone.

Table 5. Elements of a comprehensive lifestyle approach to NAFLD treatment

Area	Suggested intervention	Supportive literature*
Energy restriction	500–1,000 kcal energy defect, to induce a weight loss of 500–1,000 g/week 7–10% total weight loss target Long-term maintenance approach, combining physical activity according to the principles of cognitive-behavioural treatment	Calorie restriction drives weight loss and the reduction of liver fat, independent of the macronutrient composition of the diet [107] A 12-month intensive lifestyle intervention with an average 8% weight loss leads to significant reduction of hepatic steatosis [108]. Hepatic fat increases along with total body fat regain, but most of the beneficial metabolic effects are maintained and progression to T2DM is delayed [109].
Macronutrient composition	Low-to-moderate fat and moderate-to-high carbohydrate intake Low-carbohydrate ketogenic diets or high-protein	Adherence to the Mediterranean diet has been reported to reduce liver fat on ¹ H-MRS, when compared with a low fat/high carbohydrate diet in a crossover comparison [110, 111].
Fructose intake	Avoid fructose-containing beverages and foods	In the general population, an association has been reported between high fructose intake and NAFLD [9]
Alcohol intake	Strictly keep alcohol below the risk threshold (30 g, men; 20 g, women)	In epidemiological surveys, moderate alcohol intake (namely, wine) below the risk threshold is associated with lower prevalence of NAFLD, NASH and even lower fibrosis at histology [112–114]. Total abstinence is mandatory in NASH-cirrhosis to reduce the HCC risk [115].
Coffee drinking	No liver-related limitations	Protective in NAFLD, as in liver disease of other aetiologies, reducing histological severity and liver-related outcomes [116].
Exercise/physical activity	150–200 min/week of moderate intensity aerobic physical activities in 3–5 sessions are generally preferred (brisk walking, stationery cycling) Resistance training is also effective and promotes musculoskeletal fitness, with effects on metabolic risk factors. High rates of inactivity-promoting fatigue and daytime sleepiness reduce compliance with exercise.	Physical activity follows a dose-effect relationship and vigorous (running) rather than moderate exercise (brisk walking) carries the full benefit, including for NASH and fibrosis [110, 117, 118] Any engagement in physical activity or increase over previous levels is however better than continuing inactivity.

Relatively small amounts of weight loss reduce liver fat and improve hepatic IR [119]. In a pilot RCT of cognitive-behaviour therapy, lifestyle intervention resulted in more weight loss, more frequent resolution of NASH and a borderline higher ($p = 0.05$) reduction in the NAS score [93]. In a post hoc analysis, a weight loss $\geq 7\%$ was associated with histological improvement. In an uncontrolled, 12-month study with 261 paired biopsies, a modest life-

style-induced weight loss was associated with NASH regression (25% of total cases) without worsening of fibrosis [120].

Pragmatic approaches combining dietary restriction and a progressive increase in aerobic exercise/resistance training [121] are preferable and should be individually tailored. No data are available on their long-term effects on the natural history of NAFLD.

Recommendations

- Structured programmes aimed at lifestyle changes towards healthy diet and habitual physical activity are advisable in NAFLD (C2)
- Patients without NASH or fibrosis should only receive counselling for healthy diet and physical activity and no pharmacotherapy for their liver condition (B2)
- In overweight/obese NAFLD, a 7–10% weight loss is the target of most lifestyle interventions, and results in improvement of liver enzymes and histology (B1)
- Dietary recommendations should consider energy restriction and exclusion of NAFLD-promoting components (processed food, and foods and beverages high in added fructose). The macronutrient composition should be adjusted according to the Mediterranean diet (B1)
- Both aerobic exercise and resistance training effectively reduce liver fat. The choice of training should be tailored based on patients' preferences to be maintained in the long-term (B2)

Drug Treatment

Rationale: Drug therapy should be indicated for progressive NASH (bridging fibrosis and cirrhosis) but also for early-stage NASH with increased risk of fibrosis progression (age > 50 years; diabetes, MetS, increased ALT [122]) or active NASH with high necroinflammatory activity [123]. No drug has currently been tested in phase III trials and is approved for NASH by regulatory agencies. Therefore, no specific therapy can be firmly recommended and any drug treatment would be off-label (for reviews see [124–126], table 4). Safety and tolerability are essential prerequisites for drug treatment, because of NASH-associated comorbidities and polypharmacy, a potential source of drug-drug interactions.

Insulin Sensitisers

There is scarce evidence for a histological efficacy of metformin in NASH [84, 90, 92]. The effect of metformin on liver fat is weak, because of its inability to restore serum adiponectin levels in the short-term [127]. Some preclinical data support an anti-tumorigenic activity of metformin on liver cancer [128], while the demonstration of reduced rates of HCC in humans is limited to retrospective studies [129] and insufficient for evidence-based recommendations.

Thiazolidinediones are peroxisome proliferator-activated receptor gamma (PPAR γ) agonists with insulin-sensitising effects. The PIVENS trial compared low dose pioglitazone vs. vitamin E vs. placebo for 2 years in patients without overt diabetes. Pioglitazone improved all histological features (except for fibrosis) and achieved resolution of NASH more often than placebo [95]. The histological benefit occurred together with ALT improvement and partial correction of IR. Similar results were reported in two smaller and shorter RCTs [85, 89]. Prolonged therapy with rosiglitazone, up to 2 years, did not result in further histological improvement [88, 94], although this was not formally tested with pioglitazone. Side effects of glitazones are of concern: weight gain, bone fractures in women, and rarely congestive heart failure. Despite the safety and tolerability profile, pioglitazone can be used for selected patients with NASH, particularly in T2DM where the drug has a registered use.

Incretin mimetics, acting on the glucose-insulin interplay have shown favourable results in pre-marketing studies on liver enzymes [130]. A small pilot trial of daily injections of liraglutide met the histological outcome of NASH remission without worsening of fibrosis [105].

Antioxidants, Cytoprotective and Lipid-Lowering Agents

In the PIVENS trial, vitamin E (800 IU/day) improved steatosis, inflammation and ballooning and induced resolution of NASH in 36% of patients (21% in the placebo arm) [95]. Reduced ALT correlated with histological improvement, and histological non-responders did not reduce ALT [131]. In the paediatric TONIC trial [98], vitamin E failed to reduce aminotransferases, steatosis and inflammation but improved ballooning and doubled the rate of NASH clearance vs. placebo. These results contrast with previous trials, which were mostly negative in both adults and children. Concerns about long-term safety of vitamin E exist, mainly an increase in overall mortality [132], in haemorrhagic stroke [133] and prostate cancer in males older than 50 [134]. Vitamin E may be used in non-cirrhotic non-diabetic NASH patients but further studies are needed before firm recommendations can be made.

Ursodeoxycholic acid (UDCA) has been investigated in several RCTs, at different doses and for up to 2 years, but only showed some biochemical but no histological improvements [83, 87, 96].

A synthetic farnesoid X receptor agonist, obeticholic acid, improved IR in T2DM [135]. In the phase IIb FLINT trial, a 72-week treatment with obeticholic acid in non-cirrhotic NASH patients improved all NASH lesions while improving fibrosis [99]. Main issues with safety and tolerability were increased low-density lipoprotein (LDL)-cholesterol and pruritus.

Preliminary data from small or uncontrolled studies suggested that *n*-3 polyunsaturated fatty acids (PUFAs) might reduce liver fat [136], but two trials testing PUFAs on histological outcomes were negative [102, 104]. Available data on pentoxifylline and orlistat are limited or inconclusive [86, 91, 97]. Also, data on lipid-lowering drugs are poor; recent trials with ezetimibe were negative [101, 103], whereas statins have not been adequately tested. Their use in NAFLD is safe, with no increased risk of hepatotoxicity, and may even significantly reduce aminotransferases [137].

Promising novel agents with anti-inflammatory, antifibrotic or insulin sensitising properties (dual PPAR α / δ agonists, dual chemokine receptor (CCR)2/CCR5 antagonists and fatty acid/bile acid conjugates) and antifibrotic agents (anti-lysyl oxidase-like (anti-LOXL2) monoclonal antibodies) are also being tested in late phase RCTs in NASH.

Recommendations

- Pharmacotherapy should be reserved for patients with NASH, particularly for those with significant fibrosis (stage F2 and higher). Patients with less severe disease, but at high risk of disease progression (i.e., with diabetes, MetS, persistently increased ALT, high necroinflammation) could also be candidates to prevent disease progression (B1)
- While no firm recommendations can be made, pioglitazone (most efficacy data, but off-label outside T2DM) or vitamin E (better safety and tolerability in the short term) or their combination could be used for NASH (B2)
- The optimal duration of therapy is unknown; in patients with increased ALT at baseline, treatment should be stopped if there is no reduction in aminotransferases after 6 months of therapy; in patients with normal ALT at baseline, no recommendations can be made (C2)
- Statins may be confidently used to reduce LDL-cholesterol and prevent cardiovascular risk, with no benefits or harm on liver disease. Similarly *n*-3 polyunsaturated fatty acids reduce both plasma and liver lipids, but there are no data to support their use specifically for NASH (B1)

Iron Depletion

Hepatic iron accumulation is associated with IR, and iron depletion improves IR [138]. In NAFLD, high ferritin levels are common, in the presence of variable transferrin saturation, independent of gene polymorphisms of familial hemochromatosis. In these patients, a phlebotomy programme to reduce iron stores to near iron deficiency improved the NAS score, without worsening fibrosis [100], but more data are needed.

Paediatric NAFLD

In children, diet and exercise training reduce steatosis, but do not affect ballooning, inflammation and fibrosis [139]. Although several drug-based therapies, such as vitamin E and metformin, and dietary supplementation, including probiotics and docosahexaenoic acid, have shown beneficial effects on ballooning, steatosis and inflammation, fibrotic lesions are refractory to treatment [140] and the long-term outcome of paediatric NASH remains poor [141].

Recommendations

- Diet and physical activity improve steatosis and hepatic inflammation in paediatric NAFLD, but no beneficial effects on fibrosis have ever been demonstrated. No safe drug treatment has proven effective on fibrosis in paediatric NAFLD (B1)

Bariatric (Metabolic) Surgery

In patients unresponsive to lifestyle changes and pharmacotherapy, bariatric surgery is an option for reducing weight and metabolic complications, with stable results in the long term [142]. Surrogate markers indicate that bariatric surgery is effective on NAFLD-associated liver injury, and there is also initial evidence for improved necroinflammation and fibrosis [143]. A recent cohort study with 1-year follow-up confirmed that bariatric surgery-associated weight loss cleared NASH in 85% of patients and improved fibrosis in 34% [144], although the possible benefits should be balanced against peri-/post-operative complications. No solid data on the comparative effects of different bariatric procedures on liver fat are available.

Recommendations

- By improving obesity and diabetes, bariatric (metabolic) surgery reduces liver fat and is likely to reduce NASH progression; prospective data have shown an improvement in all histological lesions of NASH, including fibrosis (B1)

Liver Transplantation

NAFLD-associated cirrhosis is among the top three indications for liver transplantation. The 3- and 5-year survival is not different in NAFLD vs. no-NAFLD; NAFLD carries a higher risk of death from cardiovascular complications and sepsis, whereas the risk of graft failure is lower [145, 146]. The overall mortality is associated with BMI and diabetes, with 50% of cases with BMI > 35 kg/m² dying within 1 year of transplantation [147]. Transplant failure (10% and 45% at 10 and 20 years, respectively [148]) in obese patients is rarely associated with recurrent NASH cirrhosis (≈2%) [146].

Recommendations

- Liver transplantation is an accepted procedure in NASH patients with end-stage liver disease, with comparable overall survival to other indications, despite a higher cardiovascular mortality. NASH patients with liver failure and/or HCC are candidates for liver transplantation (A1)

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References

- 1 Ratziu V, Bellentani S, Cortez-Pinto H, Day C, Marchesini G: A position statement on NAFLD/NASH based on the EASL 2009 special conference. *J Hepatol* 2010;53:372–384.
- 2 Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al: GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;336:924–926.
- 3 Bellentani S, Saccoccio G, Masutti F, Croce LS, Brandi G, Sasso F, et al: Prevalence of and risk factors for hepatic steatosis in Northern Italy. *Ann Intern Med* 2000;132:112–117.
- 4 Vernon G, Baranova A, Younossi ZM: Systematic review: the epidemiology and natural history of non-alcoholic fatty liver disease and non-alcoholic steatohepatitis in adults. *Aliment Pharmacol Ther* 2011;34:274–285.
- 5 Younossi ZM, Stepanova M, Negro F, Hallaji S, Younossi Y, Lam B, et al: Nonalcoholic fatty liver disease in lean individuals in the United States. *Medicine* 2012;91:319–327.
- 6 Fracanzani AL, Valenti L, Bugianesi E, Andreoletti M, Colli A, Vanni E, et al: Risk of severe liver disease in NAFLD with normal aminotransferase levels: a role for insulin resistance and diabetes. *Hepatology* 2008;48:792–798.
- 7 Marchesini G, Mazzotti A: NAFLD incidence and remission: only a matter of weight gain and weight loss? *J Hepatol* 2015;62:15–17.
- 8 Chalasani N, Younossi Z, Lavine JE, Diehl AM, Brunt EM, Cusi K, et al: The diagnosis and management of non-alcoholic fatty liver disease: practice Guideline by the American Association for the Study of Liver Diseases, American College of Gastroenterology, and the American Gastroenterological Association. *Hepatology* 2012;55:2005–2023.
- 9 Barrera F, George J: The role of diet and nutritional intervention for the management of patients with NAFLD. *Clin Liver Dis* 2014;18:91–112.
- 10 Chiu S, Sievenpiper JL, de Souza RJ, Cozma AI, Mirrahimi A, Carleton AJ, et al: Effect of fructose on markers of non-alcoholic fatty liver disease (NAFLD): a systematic review and meta-analysis of controlled feeding trials. *Eur J Clin Nutr* 2014;68:416–423.
- 11 Gerber L, Otgonsuren M, Mishra A, Escheik C, Birendinc A, Stepanova M, et al: Non-alcoholic fatty liver disease (NAFLD) is associated with low level of physical activity: a population-based study. *Aliment Pharmacol Ther* 2012;36:772–781.
- 12 Anstee QM, Targher G, Day CP: Progression of NAFLD to diabetes mellitus, cardiovascular disease or cirrhosis. *Nat Rev Gastroenterol Hepatol* 2013;10:330–344.
- 13 Valenti L, Al-Serri A, Daly AK, Galmozzi E, Rametta R, Dongiovanni P, et al: Homozygosity for the patatin-like phospholipase-3/adiponutrin I148M polymorphism influences liver fibrosis in patients with nonalcoholic fatty liver disease. *Hepatology* 2010;51:1209–1217.
- 14 Liu YL, Patman GL, Leathart JB, Piguat AC, Burt AD, Dufour JF, et al: Carriage of the PNPLA3 rs738409 C>G polymorphism confers an increased risk of non-alcoholic fatty liver disease associated hepatocellular carcinoma. *J Hepatol* 2014;61:75–81.
- 15 Liu YL, Reeves HL, Burt AD, Tiniakos D, McPherson S, Leathart JB, et al: TM6SF2 rs58542926 influences hepatic fibrosis progression in patients with non-alcoholic fatty liver disease. *Nat Commun* 2014;5:4309.
- 16 Dongiovanni P, Petta S, Maglio C, Fracanzani AL, Pipitone R, Mozzi E, et al: Transmembrane 6 superfamily member 2 gene variant disentangles nonalcoholic steatohepatitis from cardiovascular disease. *Hepatology* 2015;61:506–514.
- 17 Valenti L, Alisi A, Galmozzi E, Bartuli A, Del Menico B, Alterio A, et al: I148M patatin-like phospholipase domain-containing 3 gene variant and severity of pediatric nonalcoholic fatty liver disease. *Hepatology* 2010;52:1274–1280.
- 18 Nobili V, Donati B, Panera N, Vongsakulyanon A, Alisi A, Dallapiccola B, et al: A 4-polymorphism risk score predicts steatohepatitis in children with nonalcoholic fatty liver disease. *J Pediatr Gastroenterol Nutr* 2014;58:632–636.
- 19 Ratziu V, Charlotte F, Heurtier A, Gombert S, Giral P, Bruckert E, et al: Sampling variability of liver biopsy in nonalcoholic fatty liver disease. *Gastroenterology* 2005;128:1898–1906.
- 20 Kleiner DE, Brunt EM: Nonalcoholic fatty liver disease: pathologic patterns and biopsy evaluation in clinical research. *Semin Liver Dis* 2012;32:3–13.
- 21 Kleiner DE, Brunt EM, Van Natta M, Behling C, Contos MJ, Cummings OW, et al: Design and validation of a histological scoring system for nonalcoholic fatty liver disease. *Hepatology* 2005;41:1313–1321.
- 22 Bedossa PFLIP Pathology Consortium: Utility and appropriateness of the fatty liver inhibition of progression (FLIP) algorithm and steatosis, activity, and fibrosis (SAF) score in the evaluation of biopsies of nonalcoholic fatty liver disease. *Hepatology* 2014;60:565–575.
- 23 Brunt EM, Kleiner DE, Wilson LA, Belt P, Neuschwander-Tetri BA, Network NCR: Nonalcoholic fatty liver disease (NAFLD) activity score and the histopathologic diagnosis in NAFLD: distinct clinicopathologic meanings. *Hepatology* 2011;53:810–820.
- 24 Ekstedt M, Hagstrom H, Nasr P, Fredrikson M, Stal P, Kechagias S, et al: Fibrosis stage is the strongest predictor for disease-specific mortality in NAFLD after up to 33 years of follow-up. *Hepatology* 2015;61:1547–1554.
- 25 Brunt EM, Kleiner DE, Wilson LA, Unalp A, Behling CE, Lavine JE, et al: Portal chronic inflammation in nonalcoholic fatty liver disease (NAFLD): a histologic marker of advanced NAFLD-Clinicopathologic correlations from the nonalcoholic steatohepatitis clinical research network. *Hepatology* 2009;49:809–820.

- 26 Alkhoury N, De Vito R, Alisi A, Yerian L, Lopez R, Feldstein AE, et al: Development and validation of a new histological score for pediatric nonalcoholic fatty liver disease. *J Hepatol* 2012;57:1312–1318.
- 27 Saadeh S, Younossi ZM, Remer EM, Gramlich T, Ong JP, Hurley M, et al: The utility of radiological imaging in nonalcoholic fatty liver disease. *Gastroenterology* 2002;123:745–750.
- 28 Fishbein M, Castro F, Cheruku S, Jain S, Webb B, Gleason T, et al: Hepatic MRI for fat quantitation: its relationship to fat morphology, diagnosis, and ultrasound. *J Clin Gastroenterol* 2005;39:619–625.
- 29 Ryan CK, Johnson LA, Germin BI, Marcos A: One hundred consecutive hepatic biopsies in the workup of living donors for right lobe liver transplantation. *Liver Transpl* 2002;8:1114–1122.
- 30 Fedchuk L, Nascimbeni F, Pais R, Charlotte F, Housset C, Ratzin V, et al: Performance and limitations of steatosis biomarkers in patients with nonalcoholic fatty liver disease. *Aliment Pharmacol Ther* 2014;40:1209–1222.
- 31 Machado MV, Cortez-Pinto H: Non-invasive diagnosis of non-alcoholic fatty liver disease. A critical appraisal. *J Hepatol* 2013;58:1007–1019.
- 32 European Association for the Study of the Liver, Asociacion Latinoamericana para el Estudio del Hígado: EASL-ALEH Clinical Practice Guidelines: non-invasive tests for evaluation of liver disease severity and prognosis. *J Hepatol* 2015;63:237–264.
- 33 Cusi K, Chang Z, Harrison S, Lomonaco R, Bril F, Orsak B, et al: Limited value of plasma cytokeratin-18 as a biomarker for NASH and fibrosis in patients with non-alcoholic fatty liver disease. *J Hepatol* 2014;60:167–174.
- 34 Kwok R, Tse YK, Wong GL, Ha Y, Lee AU, Ngu MC, et al: Systematic review with meta-analysis: non-invasive assessment of non-alcoholic fatty liver disease—the role of transient elastography and plasma cytokeratin-18 fragments. *Aliment Pharmacol Ther* 2014;39:254–269.
- 35 Vuppalanchi R, Jain AK, Deppe R, Yates K, Comerford M, Masuoka HC, et al: Relationship between changes in serum levels of keratin 18 and changes in liver histology in children and adults with nonalcoholic fatty liver disease. *Clin Gastroenterol Hepatol* 2014;12:e2121–e2122.
- 36 Guha IN, Parkes J, Roderick P, Chattopadhyay D, Cross R, Harris S, et al: Noninvasive markers of fibrosis in nonalcoholic fatty liver disease: validating the European Liver Fibrosis Panel and exploring simple markers. *Hepatology* 2008;47:455–460.
- 37 McPherson S, Anstee QM, Henderson E, Day CP, Burt AD: Are simple noninvasive scoring systems for fibrosis reliable in patients with NAFLD and normal ALT levels? *Eur J Gastroenterol Hepatol* 2013;25:652–658.
- 38 Wong VW, Vergniol J, Wong GL, Foucher J, Chan HL, Le Bail B, et al: Diagnosis of fibrosis and cirrhosis using liver stiffness measurement in nonalcoholic fatty liver disease. *Hepatology* 2010;51:454–462.
- 39 Castera L, Foucher J, Bernard PH, Carvalho F, Allaix D, Merrouche W, et al: Pitfalls of liver stiffness measurement: a 5-year prospective study of 13,369 examinations. *Hepatology* 2010;51:828–835.
- 40 Wong VW, Vergniol J, Wong GL, Foucher J, Chan AW, Chermak F, et al: Liver stiffness measurement using XL probe in patients with nonalcoholic fatty liver disease. *Am J Gastroenterol* 2012;107:1862–1871.
- 41 Petta S, Vanni E, Bugianesi E, Di Marco V, Camma C, Cabibi D, et al: The combination of liver stiffness measurement and NAFLD fibrosis score improves the noninvasive diagnostic accuracy for severe liver fibrosis in patients with nonalcoholic fatty liver disease. *Liver Int* 2015;35:1566–1573.
- 42 Vajro P, Lenta S, Socha P, Dhawan A, McKiernan P, Baumann U, et al: Diagnosis of nonalcoholic fatty liver disease in children and adolescents: position paper of the ESPGHAN Hepatology Committee. *J Pediatr Gastroenterol Nutr* 2012;54:700–713.
- 43 Nobili V, Svegliati-Baroni G, Alisi A, Miele L, Valenti L, Vajro P: A 360-degree overview of paediatric NAFLD: recent insights. *J Hepatol* 2013;58:1218–1229.
- 44 Gaggini M, Morelli M, Buzzigoli E, DeFronzo RA, Bugianesi E, Gastaldelli A: Non-alcoholic fatty liver disease (NAFLD) and its connection with insulin resistance, dyslipidemia, atherosclerosis and coronary heart disease. *Nutrients* 2013;5:1544–1560.
- 45 Alberti A, Vario A, Ferrari A, Pistis R: Review article: chronic hepatitis C– natural history and cofactors. *Aliment Pharmacol Ther* 2005;22:74–78.
- 46 Koliaki C, Szendroedi J, Kaul K, Jelenik T, Nowotny P, Jankowiak F, et al: Adaptation of hepatic mitochondrial function in humans with nonalcoholic fatty liver is lost in steatohepatitis. *Cell Metab* 2015;21:739–746.
- 47 Yki-Järvinen H: Non-alcoholic fatty liver disease as a cause and a consequence of metabolic syndrome. *Lancet Diabetes Endocrinol* 2014;2:901–910.
- 48 Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC: Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 1985;28:412–419.
- 49 McPherson S, Hardy T, Henderson E, Burt AD, Day CP, Anstee QM: Evidence of NAFLD progression from steatosis to fibrosing-steatohepatitis using paired biopsies: implications for prognosis and clinical management. *J Hepatol* 2015;62:1148–1155.
- 50 Pais R, Charlotte F, Fedchuk L, Bedossa P, Lebray P, Poynard T, et al: A systematic review of follow-up biopsies reveals disease progression in patients with non-alcoholic fatty liver. *J Hepatol* 2013;59:550–556.
- 51 Bedogni G, Miglioli L, Masutti F, Tiribelli C, Marchesini G, Bellentani S: Prevalence of and risk factors for nonalcoholic fatty liver disease: the Dionysos nutrition and liver study. *Hepatology* 2005;42:44–52.
- 52 Frith J, Day CP, Robinson L, Elliott C, Jones DE, Newton JL: Potential strategies to improve uptake of exercise interventions in non-alcoholic fatty liver disease. *J Hepatol* 2010;52:112–116.

- 53 Caldwell SH, Crespo DM: The spectrum expanded: cryptogenic cirrhosis and the natural history of non-alcoholic fatty liver disease. *J Hepatol* 2004;40:578–584.
- 54 Aron-Wisnewsky J, Minville C, Tordjman J, Levy P, Bouillot JL, Basdevant A, et al: Chronic intermittent hypoxia is a major trigger for non-alcoholic fatty liver disease in morbid obese. *J Hepatol* 2012;56:225–233.
- 55 Gomez-Ambrosi J, Silva C, Galofre JC, Escalada J, Santos S, Millan D, et al: Body mass index classification misses subjects with increased cardiometabolic risk factors related to elevated adiposity. *Int J Obes (Lond)* 2012;36:286–294.
- 56 Chang Y, Ryu S, Suh BS, Yun KE, Kim CW, Cho SI: Impact of BMI on the incidence of metabolic abnormalities in metabolically healthy men. *Int J Obes (Lond)* 2012;36:1187–1194.
- 57 Gomez-Ambrosi J, Catalan V, Rodriguez A, Andrada P, Ramirez B, Ibanez P, et al: Increased cardiometabolic risk factors and inflammation in adipose tissue in obese subjects classified as metabolically healthy. *Diabetes Care* 2014;37:2813–2821.
- 58 Ghouri N, Preiss D, Sattar N: Liver enzymes, nonalcoholic fatty liver disease, and incident cardiovascular disease: a narrative review and clinical perspective of prospective data. *Hepatology* 2010;52:1156–1161.
- 59 Gastaldelli A, Cusi K, Pettiti M, Hardies J, Miyazaki Y, Berria R, et al: Relationship between hepatic/visceral fat and hepatic insulin resistance in nondiabetic and type 2 diabetic subjects. *Gastroenterology* 2007;133:496–506.
- 60 Kotronen A, Juurinen L, Hakkarainen A, Westerbacka J, Corner A, Bergholm R, et al: Liver fat is increased in type 2 diabetic patients and underestimated by serum alanine aminotransferase compared with equally obese nondiabetic subjects. *Diabetes Care* 2008;31:165–169.
- 61 Loomba R, Abraham M, Unalp A, Wilson L, Lavine J, Doo E, et al: Association between diabetes, family history of diabetes, and risk of nonalcoholic steatohepatitis and fibrosis. *Hepatology* 2012;56:943–951.
- 62 Armstrong MJ, Adams LA, Canbay A, Syn WK: Extrahepatic complications of nonalcoholic fatty liver disease. *Hepatology* 2014;59:1174–1197.
- 63 American Diabetes Association: Standards of medical care in diabetes– 2014. *Diabetes Care* 2014;37:S14–S80.
- 64 Ortiz-Lopez C, Lomonaco R, Orsak B, Finch J, Chang Z, Kochunov VG, et al: Prevalence of prediabetes and diabetes and metabolic profile of patients with nonalcoholic fatty liver disease (NAFLD). *Diabetes Care* 2012;35:873–878.
- 65 Juurinen L, Tiikkainen M, Häkkinen AM, Hakkarainen A, Yki-Järvinen H: Effects of insulin therapy on liver fat content and hepatic insulin sensitivity in patients with type 2 diabetes. *Am J Physiol Endocrinol Metab* 2007;292:E829–E835.
- 66 Llauro G, Sevastianova K, Sadevirta S, Hakkarainen A, Lundbom N, Orho-Melander M, et al: Liver fat content and hepatic insulin sensitivity in overweight patients with type 1 diabetes. *J Clin Endocrinol Metab* 2015;100:607–616.
- 67 Anderwald C, Bernroider E, Krssak M, Stingl H, Brehm A, Bischof MG, et al: Effects of insulin treatment in type 2 diabetic patients on intracellular lipid content in liver and skeletal muscle. *Diabetes* 2002;51:3025–3032.
- 68 Singh S, Allen AM, Wang Z, Prokop LJ, Murad MH, Loomba R: Fibrosis progression in nonalcoholic fatty liver vs nonalcoholic steatohepatitis: a systematic review and meta-analysis of paired-biopsy studies. *Clin Gastroenterol Hepatol* 2015;13:643–654, e641–e649; quiz e639–e640.
- 69 Haffladottir S, Jonasson JG, Norland H, Einarsdottir SO, Kleiner DE, Lund SH, et al: Long-term follow-up and liver-related death rate in patients with non-alcoholic and alcoholic related fatty liver disease. *BMC Gastroenterol* 2014;14:166.
- 70 Kim D, Kim WR, Kim HJ, Therneau TM: Association between noninvasive fibrosis markers and mortality among adults with nonalcoholic fatty liver disease in the United States. *Hepatology* 2013;57:1357–1365.
- 71 Schwimmer JB, Behling C, Newbury R, Deutsch R, Nievergelt C, Schork NJ, et al: Histopathology of pediatric nonalcoholic fatty liver disease. *Hepatology* 2005;42:641–649.
- 72 Oni ET, Agatston AS, Blaha MJ, Fialkow J, Cury R, Sposito A, et al: A systematic review: burden and severity of subclinical cardiovascular disease among those with nonalcoholic fatty liver; should we care? *Atherosclerosis* 2013;230:258–267.
- 73 Targher G, Day CP, Bonora E: Risk of cardiovascular disease in patients with nonalcoholic fatty liver disease. *N Engl J Med* 2010;363:1341–1350.
- 74 Bhatia LS, Curzen NP, Calder PC, Byrne CD: Non-alcoholic fatty liver disease: a new and important cardiovascular risk factor? *Eur Heart J* 2012;33:1190–1200.
- 75 Calori G, Lattuada G, Ragona F, Garancini MP, Crosignani P, Villa M, et al: Fatty liver index and mortality: the Cremona study in the 15th year of follow-up. *Hepatology* 2011;54:145–152.
- 76 Pacifico L, Chiesa C, Anania C, De Merulis A, Osborn JF, Romaggioli S, et al: Nonalcoholic fatty liver disease and the heart in children and adolescents. *World J Gastroenterol* 2014;20:9055–9071.
- 77 Dyson J, Jaques B, Chattopadhyay D, Lochan R, Graham J, Das D, et al: Hepatocellular cancer: the impact of obesity, type 2 diabetes and a multidisciplinary team. *J Hepatol* 2014;60:110–117.
- 78 Wong RJ, Cheung R, Ahmed A: Nonalcoholic steatohepatitis is the most rapidly growing indication for liver transplantation in patients with hepatocellular carcinoma in the U.S.. *Hepatology* 2014;59:2188–2195.
- 79 Musso G, Gambino R, Tabibian JH, Ekstedt M, Kechagias S, Hamaguchi M, et al: Association of non-alcoholic fatty liver disease with chronic kidney disease: a systematic review and meta-analysis. *PLoS Med* 2014;11:e1001680.

- 80 Targher G, Bertolini L, Chonchol M, Rodella S, Zoppini G, Lippi G, et al: Nonalcoholic fatty liver disease is independently associated with an increased prevalence of chronic kidney disease and retinopathy in type 1 diabetic patients. *Diabetologia* 2010;53:1341–1348.
- 81 Kim NH, Park J, Kim SH, Kim YH, Kim DH, Cho GY, et al: Non-alcoholic fatty liver disease, metabolic syndrome and subclinical cardiovascular changes in the general population. *Heart* 2014;100:938–943.
- 82 Hazlehurst JM, Tomlinson JW: Non-alcoholic fatty liver disease in common endocrine disorders. *Eur J Endocrinol* 2013;169:R27–R37.
- 83 Lindor KD, Kowdley KV, Heathcote EJ, Harrison ME, Jorgensen R, Angulo P, et al: Ursodeoxycholic acid for treatment of nonalcoholic steatohepatitis: results of a randomized trial. *Hepatology* 2004;39:770–778.
- 84 Bugianesi E, Gentilecore E, Manini R, Natale S, Vanni E, Villanova N, et al: A randomized controlled trial of metformin versus vitamin E or prescriptive diet in nonalcoholic fatty liver disease. *Am J Gastroenterol* 2005;100:1082–1090.
- 85 Belfort R, Harrison SA, Brown K, Darland C, Finch J, Hardies J, et al: A placebo-controlled trial of pioglitazone in subjects with nonalcoholic steatohepatitis. *N Engl J Med* 2006;355:2297–2307.
- 86 Zelber-Sagi S, Kessler A, Brazowsky E, Webb M, Lurie Y, Santo M, et al: A double-blind randomized placebo-controlled trial of orlistat for the treatment of nonalcoholic fatty liver disease. *Clin Gastroenterol Hepatol* 2006;4:639–644.
- 87 Dufour JF, Oneta CM, Gonvers JJ, Bihl F, Cerny A, Cereda JM, et al: Randomized placebo-controlled trial of ursodeoxycholic acid with vitamin E in nonalcoholic steatohepatitis. *Clin Gastroenterol Hepatol* 2006;4:1537–1543.
- 88 Ratzliff V, Giral P, Jacqueminet S, Charlotte F, Hartemann-Heurtier A, Serfaty L, et al: Rosiglitazone for nonalcoholic steatohepatitis: one-year results of the randomized placebo-controlled Fatty Liver Improvement with Rosiglitazone Therapy (FLIRT) Trial. *Gastroenterology* 2008;135:100–110.
- 89 Aithal GP, Thomas JA, Kaye PV, Lawson A, Ryder SD, Spendlove I, et al: Randomized, placebo-controlled trial of pioglitazone in nondiabetic subjects with nonalcoholic steatohepatitis. *Gastroenterology* 2008;135:1176–1184.
- 90 Haukeland JW, Konopski Z, Eggesbo HB, von Volkmann HL, Raschpichler G, Bjoro K, et al: Metformin in patients with non-alcoholic fatty liver disease: a randomized, controlled trial. *Scand J Gastroenterol* 2009;44:853–860.
- 91 Harrison SA, Fecht W, Brunt EM, Neuschwander-Tetri BA: Orlistat for overweight subjects with nonalcoholic steatohepatitis: a randomized, prospective trial. *Hepatology* 2009;49:80–86.
- 92 Shields WW, Thompson KE, Grice GA, Harrison SA, Coyle WJ: The effect of metformin and standard therapy versus standard therapy alone in nondiabetic patients with insulin resistance and nonalcoholic steatohepatitis (NASH): a pilot trial. *Therap Adv Gastroenterol* 2009;2:157–163.
- 93 Promrat K, Kleiner DE, Niemeier HM, Jackvony E, Kearns M, Wands JR, et al: Randomized controlled trial testing the effects of weight loss on nonalcoholic steatohepatitis. *Hepatology* 2010;51:121–129.
- 94 Ratzliff V, Charlotte F, Bernhardt C, Giral P, Halbron M, Lenaour G, et al: Long-term efficacy of rosiglitazone in nonalcoholic steatohepatitis: results of the fatty liver improvement by rosiglitazone therapy (FLIRT 2) extension trial. *Hepatology* 2010;51:445–453.
- 95 Sanyal AJ, Chalasani N, Kowdley KV, McCullough A, Diehl AM, Bass NM, et al: Pioglitazone, vitamin E, or placebo for nonalcoholic steatohepatitis. *N Engl J Med* 2010;362:1675–1685.
- 96 Leuschner UF, Lindenthal B, Herrmann G, Arnold JC, Rossle M, Cordes HJ, et al: High-dose ursodeoxycholic acid therapy for nonalcoholic steatohepatitis: a double-blind, randomized, placebo-controlled trial. *Hepatology* 2010;52:472–479.
- 97 Zein CO, Yerian LM, Gogate P, Lopez R, Kirwan JP, Feldstein AE, et al: Pentoxifylline improves nonalcoholic steatohepatitis: a randomized placebo-controlled trial. *Hepatology* 2011;54:1610–1619.
- 98 Lavine JE, Schwimmer JB, Van Natta ML, Molleston JP, Murray KF, Rosenthal P, et al: Effect of vitamin E or metformin for treatment of nonalcoholic fatty liver disease in children and adolescents: the TONIC randomized controlled trial. *JAMA* 2011;305:1659–1668.
- 99 Neuschwander-Tetri BA, Loomba R, Sanyal AJ, Lavine JE, Van Natta ML, Abdelmalek MF, et al: Farnesoid X nuclear receptor ligand obeticholic acid for non-cirrhotic, non-alcoholic steatohepatitis (FLINT): a multicentre, randomised, placebo-controlled trial. *Lancet* 2015;385:956–965.
- 100 Valenti L, Fracanzani AL, Dongiovanni P, Rovida S, Rametta R, Fatta E, et al: A randomized trial of iron depletion in patients with nonalcoholic fatty liver disease and hyperferritinemia. *World J Gastroenterol* 2014;20:3002–3010.
- 101 Takeshita Y, Takamura T, Honda M, Kita Y, Zen Y, Kato K, et al: The effects of ezetimibe on non-alcoholic fatty liver disease and glucose metabolism: a randomised controlled trial. *Diabetologia* 2014;57:878–890.
- 102 Sanyal AJ, Abdelmalek MF, Suzuki A, Cummings OW, Chojkier M; EPE-A Study Group: No significant effects of ethyl-eicosapentanoic acid on histologic features of nonalcoholic steatohepatitis in a phase 2 trial. *Gastroenterology* 2014;147:e377–384.e1.
- 103 Loomba R, Sirlin CB, Ang B, Bettencourt R, Jain R, Salotti J, et al: Ezetimibe for the treatment of nonalcoholic steatohepatitis: assessment by novel magnetic resonance imaging and magnetic resonance elastography in a randomized trial (MOZART trial). *Hepatology* 2015;61:1239–1250.
- 104 Argo CK, Patrie JT, Lackner C, Henry TD, de Lange EE, Weltman AL, et al: Effects of n-3 fish oil on metabolic and histological parameters in NASH: a double-blind, randomized, placebo-controlled trial. *J Hepatol* 2015;62:190–197.

- 105 Armstrong MJ, Gaunt P, Aithal GP, Barton D, Hull D, Parker R, et al: Liraglutide safety and efficacy in patients with non-alcoholic steatohepatitis (LEAN): a multicentre, double-blind, randomised, placebo-controlled phase 2 study. *Lancet* 2015;doi: 10.1016/S0140-6736(15)00803-X.
- 106 Zelber-Sagi S, Ratzliff V, Oren R: Nutrition and physical activity in NAFLD: an overview of the epidemiological evidence. *World J Gastroenterol* 2011;17:3377–3389.
- 107 Boden G: High- or low-carbohydrate diets: which is better for weight loss, insulin resistance, and fatty livers? *Gastroenterology* 2009;136:1490–1492.
- 108 Lazo M, Solga SF, Horska A, Bonekamp S, Diehl AM, Brancati FL, et al: Effect of a 12-month intensive lifestyle intervention on hepatic steatosis in adults with type 2 diabetes. *Diabetes Care* 2010;33:2156–2163.
- 109 Perreault L, Pan Q, Mather KJ, Watson KE, Hamman RF, Kahn SE: Effect of regression from prediabetes to normal glucose regulation on long-term reduction in diabetes risk: results from the Diabetes Prevention Program Outcomes Study. *Lancet* 2012;379:2243–2251.
- 110 Thoma C, Day CP, Trenell MI: Lifestyle interventions for the treatment of non-alcoholic fatty liver disease in adults: a systematic review. *J Hepatol* 2012;56:255–266.
- 111 Ryan MC, Itsiopoulos C, Thodis T, Ward G, Trost N, Hofferberth S, et al: The Mediterranean diet improves hepatic steatosis and insulin sensitivity in individuals with non-alcoholic fatty liver disease. *J Hepatol* 2013;59:138–143.
- 112 Liangpunsakul S, Chalasani N: What should we recommend to our patients with NAFLD regarding alcohol use? *Am J Gastroenterol* 2012;107:976–978.
- 113 Kwon HK, Greenon JK, Conjeevaram HS: Effect of lifetime alcohol consumption on the histological severity of non-alcoholic fatty liver disease. *Liver Int* 2014;34:129–135.
- 114 Dunn W, Sanyal AJ, Brunt EM, Unalp-Arida A, Donohue M, McCullough AJ, et al: Modest alcohol consumption is associated with decreased prevalence of steatohepatitis in patients with non-alcoholic fatty liver disease (NAFLD). *J Hepatol* 2012;57:384–391.
- 115 Ascha MS, Hanouneh IA, Lopez R, Tamimi TA, Feldstein AF, Zein NN: The incidence and risk factors of hepatocellular carcinoma in patients with nonalcoholic steatohepatitis. *Hepatology* 2010;51:1972–1978.
- 116 Saab S, Mallam D, Cox 2nd GA, Tong MJ: Impact of coffee on liver diseases: a systematic review. *Liver Int* 2014;34:495–504.
- 117 Keating SE, Hackett DA, George J, Johnson NA: Exercise and non-alcoholic fatty liver disease: a systematic review and meta-analysis. *J Hepatol* 2012;57:157–166.
- 118 Bacchi E, Negri C, Targher G, Faccioli N, Lanza M, Zoppini G, et al: Both resistance training and aerobic training reduce hepatic fat content in type 2 diabetic subjects with nonalcoholic fatty liver disease (the RAED2 Randomized Trial). *Hepatology* 2013;58:1287–1295.
- 119 Petersen KF, Dufour S, Befroy D, Lehrke M, Hendler RE, Shulman GI: Reversal of nonalcoholic hepatic steatosis, hepatic insulin resistance, and hyperglycemia by moderate weight reduction in patients with type 2 diabetes. *Diabetes* 2005;54:603–608.
- 120 Vilar-Gomez E, Martinez-Perez Y, Calzadilla-Bertot L, Torres-Gonzalez A, Gra-Oramas B, Gonzalez-Fabian L, et al: Weight loss via lifestyle modification significantly reduces features of nonalcoholic steatohepatitis. *Gastroenterology* 2015;149:367–378.e5; quiz e14–e15.
- 121 Rodriguez B, Torres DM, Harrison SA: Physical activity: an essential component of lifestyle modification in NAFLD. *Nat Rev Gastroenterol Hepatol* 2012;9:726–731.
- 122 Adams LA, Sanderson S, Lindor KD, Angulo P: The histological course of nonalcoholic fatty liver disease: a longitudinal study of 103 patients with sequential liver biopsies. *J Hepatol* 2005;42:132–138.
- 123 Sanyal AJ, Friedman SL, McCullough AJ, Dimick-Santos L; American Association for the Study of Liver Diseases, United States Food and Drug Administration: Challenges and opportunities in drug and biomarker development for nonalcoholic steatohepatitis: findings and recommendations from an American Association for the Study of Liver Diseases-U.S. Food and Drug Administration Joint Workshop. *Hepatology* 2015;61:1392–1405.
- 124 Younossi ZM, Reyes MJ, Mishra A, Mehta R, Henry L: Systematic review with meta-analysis: non-alcoholic steatohepatitis – a case for personalised treatment based on pathogenic targets. *Aliment Pharmacol Ther* 2014;39:3–14.
- 125 Mazzella N, Ricciardi LM, Mazzotti A, Marchesini G: The role of medications for the management of patients with NAFLD. *Clin Liver Dis* 2014;18:73–89.
- 126 Ratzliff V, Goodman Z, Sanyal A: Current efforts and trends in the treatment of NASH. *J Hepatol* 2015;62:S65–S75.
- 127 Tiikkainen M, Häkkinen AM, Korshennikov E, Nyman T, Makimattila S, Yki-Järvinen H: Effects of rosiglitazone and metformin on liver fat content, hepatic insulin resistance, insulin clearance, and gene expression in adipose tissue in patients with type 2 diabetes. *Diabetes* 2004;53:2169–2176.
- 128 Bhalla K, Hwang BJ, Dewi RE, Twaddell W, Goloubeva OG, Wong KK, et al: Metformin prevents liver tumorigenesis by inhibiting pathways driving hepatic lipogenesis. *Cancer Prev Res (Phila)* 2012;5:544–552.
- 129 Zhang ZJ, Zheng ZJ, Shi R, Su Q, Jiang Q, Kip KE: Metformin for liver cancer prevention in patients with type 2 diabetes: a systematic review and meta-analysis. *J Clin Endocrinol Metab* 2012;97:2347–2353.
- 130 Vilsboll T, Christensen M, Junker AE, Knop FK, Gluud LL: Effects of glucagonlike peptide-1 receptor agonists on weight loss: systematic review and meta-analyses of randomised controlled trials. *BMJ* 2012;344:d7771.
- 131 Hoofnagle JH, Van Natta ML, Kleiner DE, Clark JM, Kowdley KV, Loomba R, et al: Vitamin E and changes in serum alanine aminotransferase levels in patients with non-alcoholic steatohepatitis. *Aliment Pharmacol Ther* 2013;38:134–143.

- 132 Bjelakovic G, Nikolova D, Gluud LL, Simonetti RG, Gluud C: Mortality in randomized trials of antioxidant supplements for primary and secondary prevention: systematic review and meta-analysis. *JAMA* 2007;297:842–857.
- 133 Schurks M, Glynn RJ, Rist PM, Tzourio C, Kurth T: Effects of vitamin E on stroke subtypes: meta-analysis of randomised controlled trials. *BMJ* 2010;341:c5702.
- 134 Klein EA, Thompson Jr IM, Tangen CM, Crowley JJ, Lucia MS, Goodman PJ, et al: Vitamin E and the risk of prostate cancer: the Selenium and Vitamin E Cancer Prevention Trial (SELECT). *JAMA* 2011;306:1549–1556.
- 135 Mudaliar S, Henry RR, Sanyal AJ, Morrow L, Marschall HU, Kipnes M, et al: Efficacy and safety of the farnesoid X receptor agonist obeticholic acid in patients with type 2 diabetes and nonalcoholic fatty liver disease. *Gastroenterology* 2013;145:e571.
- 136 Parker HM, Johnson NA, Burdon CA, Cohn JS, O'Connor HT, George J: Omega-3 supplementation and non-alcoholic fatty liver disease: a systematic review and meta-analysis. *J Hepatol* 2012;56:944–951.
- 137 Dongiovanni P, Petta S, Mannisto V, Margherita Mancina R, Pipitone R, Karja V, et al: Statin use and nonalcoholic steatohepatitis in at risk individuals. *J Hepatol* 2015;doi: 10.1016/j.jhep.2015.05.006.
- 138 Valenti L, Fracanzani AL, Dongiovanni P, Bugianesi E, Marchesini G, Manzini P, et al: Iron depletion by phlebotomy improves insulin resistance in patients with nonalcoholic fatty liver disease and hyperferritinemia: evidence from a case-control study. *Am J Gastroenterol* 2007;102:1251–1258.
- 139 Nobili V, Alisi A, Raponi M: Pediatric non-alcoholic fatty liver disease: preventive and therapeutic value of life-style intervention. *World J Gastroenterol* 2009;15:6017–6022.
- 140 Mitchel EB, Lavine JE: Review article: the management of paediatric nonalcoholic fatty liver disease. *Aliment Pharmacol Ther* 2014;40:1155–1170.
- 141 Feldstein AE, Charatcharoenwitthaya P, Treeprasertsuk S, Benson JT, Enders FB, Angulo P: The natural history of non-alcoholic fatty liver disease in children: a follow-up study for up to 20 years. *Gut* 2009;58:1538–1544.
- 142 Schauer PR, Bhatt DL, Kirwan JP, Wolski K, Brethauer SA, Navaneethan SD, et al: Bariatric surgery versus intensive medical therapy for diabetes–3-year outcomes. *N Engl J Med* 2014;370:2002–2013.
- 143 Caiazzo R, Lassailly G, Leteurtre E, Baud G, Verkindt H, Raverdy V, et al: Roux-en-Y gastric bypass versus adjustable gastric banding to reduce nonalcoholic fatty liver disease: a 5-year controlled longitudinal study. *Ann Surg* 2014;260:893–898, Discussion 898–899.
- 144 Lassailly G, Caiazzo R, Buob D, Pigeyre M, Verkindt H, Labreuche J, et al: Bariatric surgery reduces features of non-alcoholic steatohepatitis in morbidly obese patients. *Gastroenterology* 2015;149:377–388.
- 145 Charlton MR, Burns JM, Pedersen RA, Watt KD, Heimbach JK, Dierkhising RA: Frequency and outcomes of liver transplantation for nonalcoholic steatohepatitis in the United States. *Gastroenterology* 2011;141:1249–1253.
- 146 Wang X, Li J, Riaz DR, Shi G, Liu C, Dai Y: Outcomes of liver transplantation for nonalcoholic steatohepatitis: a systematic review and meta-analysis. *Clin Gastroenterol Hepatol* 2014;12:e391.
- 147 Heuer M, Kaiser GM, Kahraman A, Banysch M, Saner FH, Mathe Z, et al: Liver transplantation in nonalcoholic steatohepatitis is associated with high mortality and post-transplant complications: a single-center experience. *Digestion* 2012;86:107–113.
- 148 Sebagh M, Samuel D, Antonini TM, Coilly A, Degli Esposti D, Roche B, et al: Twenty-year protocol liver biopsies: invasive but useful for the management of liver recipients. *J Hepatol* 2012;56:840–847.