Role of Insulin Resistance in the Development of Nonalcoholic Fatty Liver Disease in People With Type 2 Diabetes: From Bench to Patient Care

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Insulin resistance is implicated in both the pathogenesis of nonalcoholic fatty liver disease (NAFLD) and its progression from steatosis to steatohepatitis, cirrhosis, and even hepatocellular carcinoma, which is known to be more common in people with type 2 diabetes. This article reviews the role of insulin resistance in the metabolic dysfunction observed in obesity, type 2 diabetes, atherogenic dyslipidemia, and hypertension and how it is a driver of the natural history of NAFLD by promoting glucotoxicity and lipotoxicity. The authors also review the genetic and environmental factors that stimulate steatohepatitis and fibrosis progression and their relationship with cardiovascular disease and summarize guidelines supporting the treatment of NAFLD with diabetes medications that reduce insulin resistance, such as pioglitazone or glucagon-like peptide 1 receptor agonists.

People with type 2 diabetes have the highest risk of developing nonalcoholic fatty liver disease (NAFLD) (1,2). However, the high prevalence and clinical implications of this disease are just now becoming better recognized. Not only is NAFLD more common in people with type 2 diabetes, but the coexistence of NAFLD and type 2 diabetes is associated with more rapid progression to cirrhosis (3). The prevalence of NAFLD in people with type 2 diabetes has been reported to be between 60 and 86% globally (4). Recent clinical practice guidelines for NAFLD (5–9) recommend systematic screening of all people with type 2 diabetes using the Fibrosis-4 (FIB-4) index. Studies using transient elastography or MRI-based techniques have reported the prevalence of NAFLD to exceed 70% (10). Even more concerning, about half of all patients with coexisting type 2 diabetes and NAFLD have steatohepatitis (11), and about one in six have moderate to advanced fibrosis (10,12,13).

NAFLD is a multisystem disease with extrahepatic disease implications that include type 2 diabetes and cardiovascular disease (CVD) (14). Patients with NAFLD have a twofold higher risk of developing type 2 diabetes than those without NAFLD, with more severe liver disease perhaps increasing this risk (15,16). The presence of NAFLD in people with type 2 diabetes is often associated with a worse cardiometabolic profile, as well as a higher risk of more severe hypertension, atherogenic dyslipidemia, cardiac arrythmias, and cardiovascular events (17).

Why are people with type 2 diabetes at such high risk of steatohepatitis and the eventual development of cirrhosis? The answer is not straightforward, but multiple factors appear to be at play. As will be reviewed below, these include genetic factors that may modulate insulin action or hepatocyte lipid metabolism and a web of acquired factors driven by insulin resistance such as glucotoxicity and lipotoxicity linked to dysfunctional adipose tissue and ectopic fat accumulation in the liver in people with obesity and diabetes (1,2,18). Central among factors is insulin resistance, which promotes multiple alterations of glucose and lipid metabolism, intracellular inflammatory pathways, mitochondrial dysfunction, and endothelial reticulum stress (19). Among multiple mechanisms, a common finding is more severe hyperinsulinemia, atherogenic dyslipidemia, and adipose tissue, hepatic, and muscle insulin resistance (20,21).

Because of the clinical implications of insulin resistance in people with type 2 diabetes and NAFLD, this article focuses on its role in the development of the disease and how reversing insulin resistance with either weight loss (via lifestyle modification or glucagon-like peptide 1 [GLP-1] receptor agonist therapy) or use of the insulin sensitizer pioglitazone can reverse steatohepatitis and may even heal fibrosis (22). Our hope is that a better understanding of the pathophysiology of NAFLD may assist clinicians in the management of this complex condition.

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Practical Aspects of the Pathophysiology and Natural History of NAFLD

Genetic Factors Play a Role

The severity of NAFLD in a given individual is influenced by an interplay of environmental and genetic factors. Several genetic variants of clinical relevance have been identified by genome-wide association studies and candidate gene approaches. Among those associated with a greater risk of cirrhosis from steatohepatitis are patatin-like phospholipase domain–containing protein 3 (*PNPLA3*), transmembrane 6, superfamily member 2 (*TM6SF2*), glucokinase regulatory protein (*GCKR*), and membrane bound *O*-acyltransferase domain–containing 7 (*MBOAT7*), among others, while hydroxysteroid 17-β dehydrogenase 13 (*HSD17B13*) is associated with lower risk (23).

The practical value of genetic polymorphisms is that they could, in the near future, help to better estimate the future risk of developing cirrhosis and guide more aggressive treatments toward patients with higher risk. These genetic polymorphisms may explain as much as half of the interindividual variations in the risk of NAFLD and future cirrhosis. Thus, the sum of risk-increasing alleles may become a powerful clinical instrument for people with NAFLD (24). For example, genetic risk scores calculated from *PNLP3*, *TM6SF2*, *MBOAT7*, and other variants are associated with worse liver outcomes (25,26).

One of the best genetic variants studied is the triacylglycerol lipase *PNPLA3*, which regulates intracellular lipid droplet metabolism. Of note, patients with the *PNPLA3* variant are as insulin resistant as those without the mutation (1) but usually have worse steatohepatitis and higher risks not only of cirrhosis, but also of hepatocellular cancer (HCC) (27), which is amplified in the presence of obesity or diabetes (28). The *PNPLA3* variant rs738409 C>G, which encodes I148M, promotes intracellular lipid accumulation by reducing the lipidation of very-low-density lipoprotein (VLDL) cholesterol (21). A mutation in *TM6SF2*, most commonly in *E167K*, causes steatosis by intracellular retention of VLDL cholesterol within the hepatocyte (23). On the other hand, both genetic variants of *PNPLA3* and *TM6SF2* are associated with lower plasma triglyceride levels and an apparent lower risk of CVD despite higher hepatic triglycerides (29).

Defects in *MBOAT7*, of which the most common splice variant is rs72613567, also affect lipid droplet function with decreased secretion of triglycerides, mitochondrial dysfunction, increased susceptibility to steatohepatitis and fibrosis in NAFLD, alcohol-associated liver disease, and viral hepatitis (30,31). The *GCKR* rs1260326 gene variant is associated with greater rates of glycolysis and increases hepatic de novo lipogenesis (DNL) in patients with obesity and NAFLD (32). Inversely, *HSD17B13* rs72613567, a splice variant with an adenine insertion (A-INS), plays a protector role against liver disease progression, and a loss of function of the *HSD17B13* allele increases the risk of steatohepatitis (24). The genetic variants discussed above are being exploited to identify individuals at higher risk of future cirrhosis and also to develop NASH pharmacological agents targeting these pathways.

Insulin Resistance Produces Steatosis

The prevalence of hepatic steatosis is very high in individuals with type 2 diabetes, especially those with overweight or obesity, affecting at least two in three individuals in studies using transient elastography or MRI-based techniques (10). The mechanisms remain unclear, but clinicians may better understand the impact of insulin resistance by considering how insulin interacts with regulation of hepatic glucose and lipid metabolism during feeding and fasting (18,31,33).

In the fasting state, the insulin concentration is low, and skeletal muscle fundamentally relies on fatty acids from adipose tissue as their source of energy. The low insulin level promotes adipose tissue–stored triglyceride lipolysis and its release as free fatty acids (FFAs) into the plasma. In addition, low insulin, together with an increase in glucagon secretion, stimulate liver glycogen breakdown and gluconeogenesis to maintain hepatic glucose production and normal fasting plasma glucose (34). With a meal, the increment of plasma insulin concentration inhibits adipose tissue lipolysis (thereby lowering plasma FFA levels) and promotes muscle and liver glucose uptake and utilization, with a metabolic switch from fat to glucose as their main source of energy. This transition from the fasting to the fed state, with the consequent shift from FFAs to glucose as an energy substrate, is known as metabolic flexibility (18,35).

A key feature of insulin-resistant states such as obesity, NAFLD, and type 2 diabetes is their metabolic inflexibility—disruption of this important glucose-lipid (FFA) energy switch caused by insulin-resistant, dysfunctional adipose tissue (sometimes called "sick fat"). This disruption promotes a relentless, chronic excess offer of fat (FFAs) as the main source of daily energy for the liver and muscle, at the expense of glucose utilization. This chronic FFA excess energy supply, which is typical of insulin-resistant states, is known as lipotoxicity (18,36). Impaired cellular glucose uptake response to insulin, plus an excess influx of energy as FFAs from increased lipolysis of white adipose tissue, compounded by increased rates of hepatic DNL, leads to hepatic steatosis (37). The liver disposes of FFAs through mitochondrial β-oxidation, re-esterification into triglycerides, and storage in lipid droplets or its release as VLDL cholesterol into the systemic circulation.

Over-secretion of VLDL cholesterol in insulin-resistant individuals with type 2 diabetes or NAFLD causes atherogenic dyslipidemia (i.e., an increased number of apolipoprotein B particles, hypertriglyceridemia, and low HDL cholesterol) and is often proportional to the degree of hepatic triglyceride excess (32).

The accumulation of intrahepatic triglycerides may be viewed as a defense mechanism to avoid the formation of more toxic lipid intermediates (e.g., diacylglycerols and ceramides), endothelial reticulum stress, and formation of reactive oxygen species (ROS). These worsen in the transition from simple steatosis to steatohepatitis (20). Of note, relatively small increases of liver triglycerides, even within the normal range, are associated with the development of insulin resistance, atherogenic dyslipidemia, lower plasma adiponectin, and an unfavorable metabolic profile (38,39). However, the severity of steatohepatitis (i.e., necroinflammation or fibrosis) does not appear to be directly proportional to worse steatosis (38), although this finding remains controversial.

Metabolic Dysregulation From Insulin Resistance Contributes to Steatohepatitis

Nonalcoholic steatohepatitis (NASH) is a histological diagnosis defined as having, in addition to steatosis, active hepatocyte injury (ballooning) and lobular inflammation, often with liver fibrosis (5). As illustrated in Figure 1, steatosis promotes fibrosis by many different pathways, but the molecular mechanisms remain elusive, as reviewed elsewhere (40–43). However, the metabolic dysregulation that results from insulin resistance, as observed often in obesity and type 2 diabetes, is almost universal among those with steatohepatitis and is central to disease progression (1,18,44). Because insulin resistance is a clinically identifiable target with potential for intervention compared with more poorly defined molecular pathways (many of which are also affected by insulin resistance), it is important for clinicians to understand its role. This understanding is the basis for identifying and treating insulin resistance by promoting weight loss and prescribing medications that reverse it.

As previously mentioned, people with overweight or obesity have abnormal adipose tissue metabolism and peripheral insulin resistance, a state of lipotoxicity (1,2,18,44) that is often associated with hyperglycemia and chronic glucotoxicity if prediabetes or type 2 diabetes are present (45,46). Glucotoxicity and lipotoxicity associated with steatosis in obesity, type 2 diabetes, and NAFLD lead to the accumulation of toxic intracellular lipid intermediates such as diacylglycerols and ceramides, that are related to whole-body and hepatic insulin resistance, hepatocyte necroinflammation, and cellular apoptosis (41,47–50).

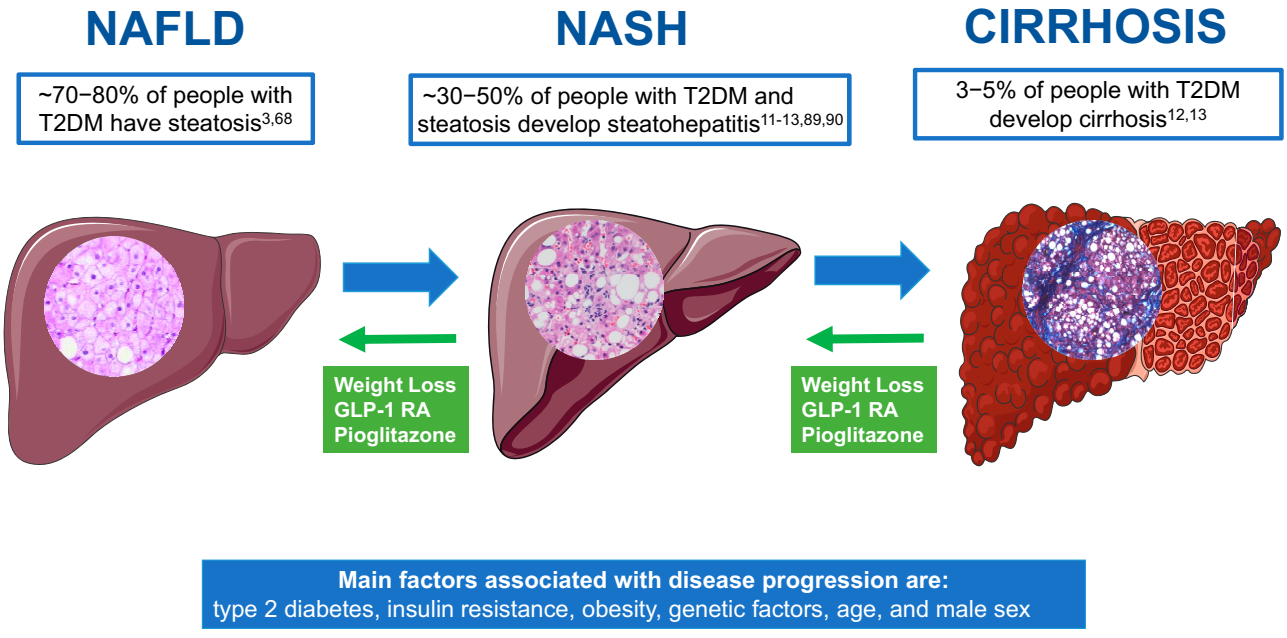

FIGURE 1 Disease progression in NAFLD. NAFLD encompasses a spectrum of liver disease, ranging from steatosis to steatohepatitis, with bouts of progression and regression from early to advanced fibrosis and cirrhosis. The more advanced the disease, the more limited the potential for regression is, until decompensated cirrhosis develops. At least 70% of people with type 2 diabetes are estimated to have NAFLD, and, among them, about half may have NASH. Fibrosis is believed to be present in 12–20% of all people with type 2 diabetes (3,11–13,65,68,89,90). RA, receptor agonist. T2DM, type 2 diabetes mellitus.

Within this context, mitochondria have been implicated in the pathogenesis of NAFLD because of their role in fatty acid oxidation, lipogenesis, and gluconeogenesis (36,41). In metabolic diseases associated with insulin resistance, to prevent steatosis, hepatic mitochondria adapt and increase FFA oxidation to dispose of the larger supply. However, in individuals with insulin resistance (i.e., obesity or type 2 diabetes) who develop steatohepatitis, this mitochondrial adaptation appears to be transient and to diminish over time, causing oxidative stress, gradually exhausting cellular antioxidative capacity, and leading to mitochondrial abnormalities (49,51; S. Kalavalapalli, D. Barb, K.C., unpublished observations). In the end, chronic insulin resistance with diminishing mitochondrial oxidative capacity creates the conditions for rapid progression from steatosis to steatohepatitis to cirrhosis (36,52,53).

Although patients with type 2 diabetes have a higher prevalence of steatosis (10), the prevalence of the associated steatohepatitis (i.e., necroinflammation) in patients in the general population has been more difficult to establish because liver biopsy is an invasive procedure and cannot be ethically justified as a tool for population-based studies.

Retrospective studies based on liver histopathology are limited by small size, spectrum bias, varying case definitions, and unclear indications for liver biopsy. However, a recent study using iron-corrected (cT1) MRI in randomly selected patients from outpatient clinics reported that the overall prevalence of steatohepatitis was 14% (11). More worrisome was that people with type 2 diabetes had a much higher prevalence (35%) compared with those without diabetes (10%) and that, in those with diabetes, obesity, and hypertension, the prevalence of NASH was almost 50%. In another recent prospective study, researchers performed liver biopsies in all people with type 2 diabetes who also had steatosis and/or elevated plasma aminotransferase (12). In this selected population, almost two-thirds had steatohepatitis and one-third had advanced fibrosis or cirrhosis. Of note, as had been reported in previous studies (20,54–57), most individuals with NASH and advanced fibrosis had normal or near-normal plasma aminotransferase levels. This finding has been the main reason for recent clinical practice guidelines recommending FIB-4 screening of all people with type 2 diabetes or metabolic syndrome (5–9), because the traditional paradigm that elevated ALT or AST should be the main criterion for additional liver testing is deeply flawed. This concept is discussed in depth elsewhere (58).

Finally, although the disease progression rate is relatively slow in most people, clinicians may be aware that progression may be faster in some individuals with risk factors, including people with insulin resistance (whether lean or with obesity), obesity, or type 2 diabetes and those with some gene variants (e.g., the *PNPLA3* variant).

Insulin Resistance, Obesity, and Type 2 Diabetes Predispose to Advanced Liver Fibrosis

Fibrosis progression is influenced by many factors, including the genomic profile and comorbidities such as obesity and type 2 diabetes (Figure 1). The underlying mechanisms are poorly understood, but they are diverse and often worsened by insulin resistance (41,59). Weight gain, obesity, and type 2 diabetes are the typical risk factors for fibrosis progression (8). Activation of inflammatory pathways in the setting of insulin resistance and metabolic dysfunction in NASH triggers M1 macrophages to secrete proinflammatory cytokines and accelerate fibrosis by promoting extracellular matrix deposition and tissue remodeling (60). This is followed by reparative phases with liver macrophages undergoing alternative activation to M2-type macrophages that promote extracellular matrix degradation (i.e., fibrolysis) (42,43). The net effect over time of fibrogenesis versus fibrolysis determines disease progression to cirrhosis.

Hepatic fibrosis, rather than inflammation, especially in insulin-resistant individuals, appears to be the key histological feature of NASH that defines the progression of the disease. This feature can be traced to the loss of mitochondrial adaptation and oxidative capacity discussed earlier for steatohepatitis. Fibrosis in individuals with NASH who have any degree of hepatic fibrosis, is associated with lower mitochondrial respiration rates than in those showing no signs of fibrosis (49,51,61; S. Kalavalapalli, D. Barb, K.C., unpublished observations). The impact of mitochondrial maladaptation points to its key role in metabolic liver injury and the development of the conditions that lead to progression to cirrhosis. In type 2 diabetes, hyperglycemia might contribute to defects in mitochondrial respiration, increased ROS, glycosylation of proteins, and increased formation of advanced glycation end products (45,46).

From a clinical perspective, advanced liver fibrosis is common in patients with type 2 diabetes (3,20). An early study reported a 17.7% prevalence of advanced fibrosis in a cohort of 1,918 individuals with type 2 diabetes from Hong Kong who were screened by transient elastography (62). More recent studies, also with transient elastography or MRI-based techniques, have reported that the prevalence of significant fibrosis (stage ≥F2) ranges between 12 and 20% (10). A recent prospective study of 501 U.S. adults with type 2 diabetes who were tested by the gold-standard MRI and elastography (MRE) technique reported a prevalence

of steatosis of 65% and of advanced fibrosis of 14%, with 6% having cirrhosis (13). Having diabetes increases the risk of major complications of cirrhosis, such as ascites, hepatic encephalopathy, bacterial infections, and chronic kidney disease, and is associated with higher mortality rates (63).

Retrospective studies often highlight type 2 diabetes as the most significant clinical factor for advanced fibrosis and cirrhosis (42). For example, a large retrospective study in 619 individuals with biopsy-confirmed NASH who were followed for a mean of 12.6 years reported that age (hazard ratio [HR] 1.07), type 2 diabetes (HR 1.62), and smoking (HR 2.62) were the most relevant factors for disease stage severity (64). Among the few prospective studies, a recent observational study reported a significantly higher prevalence of type 2 diabetes among individuals with cirrhosis (65). Individuals with type 2 diabetes who have overweight or obesity increase their risk of advanced fibrosis in proportion to their excess weight (66), making obesity prevention and screening imperative in this population. In support of the deleterious role of obesity, several studies have demonstrated that clinically significant liver fibrosis is strongly associated with adipose tissue insulin resistance (20,54,55,57,67).

The severity of liver fibrosis at baseline is another major factor (64,68). In a recent meta-analysis to quantify the prognostic value of the fibrosis stage at diagnosis, the investigators collected data from 4,428 individuals with NAFLD, 2,875 of whom had NASH, and found that worse fibrosis increased all-cause mortality by 3.4-fold and liver-related mortality by 11-fold (69). Finally, in a prospective study involving individuals with biopsy-proven NASH, all-cause mortality increased with increasing fibrosis stages (65). As expected, a more advanced fibrosis stage was associated with more liver-related complications, such as variceal hemorrhage, ascites, encephalopathy, and HCC. Of note, the prevalence of type 2 diabetes was about twofold higher among those with cirrhosis. Taking these findings together, it is clear that having type 2 diabetes significantly increases the risk of liver disease, cirrhosis, and HCC.

Clinical Implications of Insulin Resistance in NAFLD

Knowing the role of insulin resistance in the metabolic dysfunction associated with NAFLD in diabetes allows health care providers to establish targeted strategies to address it. Having steatosis is often an indication of insulin resistance once secondary causes have been be ruled out (e.g., alcohol abuse and certain medications) (8,9). Of note, not only people with type 2 diabetes can be affected, but also those with type 1 diabetes, particularly if they have obesity (8,9).

Clinical practice guidelines recommend risk-stratifying all people with steatosis or elevated liver plasma aminotransferase levels, obesity with cardiometabolic risk factors, prediabetes, or type 2 diabetes for the presence of significant hepatic fibrosis. Initial fibrosis risk stratification can be done in a cost-effective way by calculating the FIB-4 score derived from age, AST, ALT, and platelet count. A FIB-4 calculator is available online (https://www.mdcalc.com/calc/2200/fibrosis-4-fib-4-index-liver-fibrosis). Clinicians are often unaware that a FIB-4 calculator is also readily available in many existing electronic medical record (EMR) systems or that one can be easily built into a system and incorporated as a template into routine EMR notes, as discussed elsewhere in this article collection (58).

Clinicians should also be aware that diagnosis of clinically significant fibrosis (i.e., moderate to advanced fibrosis or stage $\geq$F2 on histology) and monitoring of disease progression (i.e., worsening of liver fibrosis) can be performed reasonably well in clinical practice without the need for a liver biopsy. This has been clearly shown in a recent individual-participant data meta-analysis of the prognostic performance of liver histology compared with noninvasive tests (70). In this study, 2,518 patients with biopsy-proven NAFLD were followed for a median of 57 months. Both liver fibrosis assessments, liver stiffness measurement (LSM) by transient elastography (area under the receiver operating characteristic [AUROC] curve 0.76 [95% CI 0.70–0.83]) and the FIB-4 index (AUROC curve 0.74 [95% CI 0.64–0.82]) performed well after adjustment for confounders to predict all-cause mortality, HCC, liver transplantation, and cirrhosis complications (70). Moreover, magnetic resonance (MR) techniques, either MR elastography (MRE) alone (71,72), multiparametric MRI (cT1) (73), or MR combined with plasma aminotransferase measurement (74), can assist in the assessment of treatment response to weight loss and pharmacotherapy. However, given factors such as limited MRI availability and its high cost, the use of these options is best in the hands of liver specialists working within a multidisciplinary team (5,9). This issue is discussed in further detail elsewhere in this article collection (58) in the context of clinical practice guidelines that emphasize the importance of a healthy lifestyle in the management of obesity and type 2 diabetes in people with NAFLD (5,8,9).

Table 1 summarizes the negative impacts of weight gain in humans and their reversal by two different and complementary approaches. As discussed earlier, chronic overnutrition causes a loss of normal metabolic flexibility. This loss is not only associated with the development of adipose tissue dysfunction, insulin resistance, and NASH, but also it promotes the development of type 2 diabetes and CVD. Weight gain is also associated with many symptoms that impair

TABLE 1 Effect of Weight Loss or Pioglitazone for People With Type 2 Diabetes and NAFLD

Risk Factor	Weight Gain (i.e., Overweight or Obesity)	Weight Loss (via Lifestyle Change, Bariatric Surgery, or GLP-1 Receptor Agonist Therapy)	Insulin Sensitizer (i.e., PPAR-γ Agonist Pioglitazone)
Insulin resistance • Liver fat content • Visceral fat mass • Adipocyte function (insulin sensitivity, FFA, adiponectin secretion)	Worse	Improved	Improved
Type 2 diabetes • Glycemia • Atherogenic dyslipidemia	Worse	Improved	Improved
Cardiometabolic risk • CVD • Endothelial function • Subclinical inflammation	Worse	Improved	Improved

PPAR, peroxisome proliferator–activated receptor.

quality of life (e.g., fatigue, depression, and impaired mobility). Thus, a comprehensive medical approach is needed that includes behavioral modification and the appropriate selection of individuals as candidates for pharmacotherapy or bariatric surgery (75). Weight loss in patients with NAFLD requires a long-term multidisciplinary approach with the goal of improving quality of life and helping individuals adopt a healthy eating pattern and increase their physical activity, ideally to achieve a weight loss of ≥10%. Many studies have shown that this goal is best obtained with frequent communication and trust between the health care team and patients that involves setting realistic and flexible weight loss goals and considering the use of pharmacotherapy when needed.

Although there are no approved drug therapies specifically to treat NASH, an ever-increasing number of randomized controlled trials (RCTs) have shown that weight loss by any means, including bariatric surgery, reverses steatohepatitis and halts fibrosis progression and the development of cirrhosis. Among weight loss medications, GLP-1 receptor agonists have emerged as a revolutionary approach that takes advantage of human physiology to promote weight loss. The best studied of these agents in RCTs with paired biopsies in people with NASH are liraglutide and semaglutide (76). An in-depth review of current pharmacological interventions in NAFLD is included elsewhere in this article collection (77). Lifestyle changes combined with GLP-1 receptor agonist therapy is more successful than dietary approaches alone in reducing weight by ≥10%, a weight loss threshold that has been associated with significant histological improvement of NASH (9). The beneficial effect of GLP-1 receptor agonists on the liver is closely related to the magnitude of weight loss (18,75,76). As summarized in Table 1, treatment with a GLP-1 receptor agonist is also associated with improved glycemic control, amelioration of atherogenic dyslipidemia, and other cardiometabolic benefits, which, combined, reduce cardiovascular risk.

The role of glycemic control has been controversial in the absence of RCTs designed to establish the role of improving hyperglycemia per se, independent of effects on weight or insulin resistance (1,18). Observational studies have yielded conflicting results, with some studies reporting a modest association between higher A1C and worse fibrosis (78), while others have not found an association (3,20,38,66). For example, a recent study reported that higher A1Cs were observed in people with type 2 diabetes who had NAFLD compared with those without NAFLD (6.9 vs. 6.5%), or in those with versus without NASH (7.7 vs. 7.4%). However, although both differences were statistically significant, the differences in A1C between groups was overall small, and hyperglycemia was not associated with advanced fibrosis (12). When combined, available evidence suggests that hyperglycemia in type 2 diabetes has an overall modest effect on NASH.

Pioglitazone (together with GLP-1 receptor agonists) has been incorporated into the ADA's 2023 NAFLD clinical recommendations as an option to treat NASH (9) and has also been added to other clinical practice guidelines (5–8). Several paired-biopsy RCTs document its efficacy and safety to reverse NASH in people with obesity, prediabetes, or type 2 diabetes (79–83). Recent meta-analyses have confirmed its benefit on steatohepatitis and, to a lesser degree, fibrosis (84,85). Table 1 highlights the metabolic benefits of pioglitazone, which include improvement in insulin sensitivity, glucose and lipid metabolism, and a broad spectrum of cardiometabolic factors (e.g., endothelial function, systemic inflammation, lipids, and adiponectin) (10,18,86).

The ADA's 2023 guidelines also suggest the use of pioglitazone to lower the risk of cerebrovascular events and

myocardial infarction in patients with a history of stroke who also have prediabetes and insulin resistance (9). Pioglitazone significantly decreases cardiovascular risk in patients with (87) or without (88) type 2 diabetes, as well as the progression of atherosclerosis, as reviewed elsewhere (18,86).

Conclusion

NAFLD does not happen in isolation, but rather is part of a broader metabolic dysfunction emerging from chronic insulin resistance in the context of a broad spectrum of genetic and acquired factors. The prevalence of steatosis is increasing, especially in people with type 2 diabetes (4,68). This increase is not surprising, because steatosis predisposes people to the development of type 2 diabetes (1,2). Both share a common soil of metabolic dysfunction and risk factors linked to insulin resistance. On the other hand, having type 2 diabetes greatly increases the chances of developing steatohepatitis and advanced fibrosis, as well as CVD, which is the main cause of mortality in people with NAFLD.

The best strategy for these complex patients involves early identification, proper fibrosis risk stratification, referral to a specialist when indicated, and management by a multidisciplinary health care team that can help patients take a proactive approach to reverse the metabolic dysfunction associated with insulin resistance and its comorbidities (Table 1). All clinicians must proactively act now, as we have the tools today to halt disease progression and improve quality of life for millions of people. To do nothing and let people slowly drift toward cirrhosis is the unbearable alternative.

DUALITY OF INTEREST

K.C. has received research support toward the University of Florida as a principal investigator from Echosens, Inventiva, LabCorp, and Nordic Bioscience. He is also a consultant for Aligos, Arrowhead, AstraZeneca, BMS, Boehringer Ingelheim, Covance, GSK, Eli Lilly, Madrigal, Novo Nordisk, Prosciento, Sagimet, and Siemens. No other potential conflicts of interest relevant to this article were reported.

AUTHOR CONTRIBUTIONS

Both authors contributed to writing, reviewing, and editing the manuscript. K.C. is the guarantor of this work and, as such, had full access to all materials and takes responsibility for the accuracy and integrity of the content.

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