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Machine Learning-Based Prediction and Remedy Assessment for Non-Alcoholic Fatty Liver Disease Via Ultrasound Imaging

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Abstract:

The development of effective treatment strategies is essential due to the prevalence of non-alcoholic fatty liver disease (NAFLD) worldwide. Purpose: In this study, the ML methodology on data retrieved from a multicenter ERCP database is used to evaluate and predict the effect of different therapeutic modalities for NAFLD to maximize personalizing individual treatment regimens and response management. Method: Using a large, rich dataset of biochemical biomarkers, clinical attributes, and patient demographics, this study leverages several state-of-the-art machine learning models, in particular, the VGG16 model, to detect patterns and variables related to success in treatment automatically. Result: show that the VGG16-based strategy significantly outperforms other methods in determining the success of therapy, stratifying non-alcoholic steatohepatitis (NASH) by severity of grade: I (5–33%) in mild steatosis, II (34–66%) in medium severe steatosis, and III (>66%). Aggressive Stromal Response estate costs facilitate the use of prognostic factors to predict recurrence after surgery. Conclusion: AI-based strategies can enhance understanding of NAFLD management and enable the creation of personalized nutritional and therapeutic interventions. The integration of artificial intelligence with NAFLD management appears promising, offering fresh insights into treatment algorithms for prevalent chronic liver disease. Future scope: This research should focus on expanding the dataset and adding more parameters to enhance the generalizability and refinement of prediction models.

Keywords: Artificial Intelligence, ultrasound images, remedies.

1. Introduction

Non-Alcoholic Fatty Liver Disease (NAFLD) is a progressive liver disease defined by an excess of fat in the liver cells of individuals with minimal alcohol consumption. it has become the leading cause of chronic liver disease globally, affecting an estimated 25–30% of the world population. And NAFLD has a strong association with metabolic syndrome, obesity, type 2 diabetes, dyslipidemia, and hypertension. (Younossi, 2019). NAFLD is a serious health problem because of its high prevalence. Non-alcoholic fatty liver disease is associated with overweight, resistance to insulin, diabetes type 2 mellitus (DM2), hyperlipidemia, high blood pressure, and the syndrome of metabolic disease (Guarneros-Nolasco et al., 2023). The medical spectrum of NAFLD is broad, starting with steatosis and advancing to steatohepatitis (NASH), which can lead to varied levels of cirrhosis, hepatic cancer, and fibrosis of the liver. Though there is now disagreement about the best way to treat NAFLD pharmacologically, it is obvious that treatment strategies should center on changing one's way of life.

The first line of treatment is still diet and exercise, and research suggests that in the early stages of NAFLD, a good diet and weight loss may be enough to slow the disease's development (Perdomo et al., 2019). Though there is ample proof that dietary interventions work, it is unclear how much and what kind of food should be consumed. Furthermore, patients frequently disregard nutritional recommendations. Therefore, there is a need for straightforward, interdisciplinary dietary advice that focuses on the illness causes. Furthermore, new research is beginning to lend credence to a personalized nutrition strategy that includes artificial intelligence (AI). This review concentrated on diet planning to gain a better understanding of the function that nutrients play in the pathogenesis of non-alcoholic fatty liver disease (NAFLD) (Musso et al., 2003). If a person drinks less than 20 grams of alcohol per day, they may have hepatic steatosis, which is a long-lasting and progressive condition. More than 50% of people in Mexico exhibit at least one of the NAFLD risk factors, which has been linked to the country's rising incidence of the condition. For those who suffer from NAFLD, the medium-term outlook is therefore quite bleak if prompt action is not taken to lessen what is already seen as a federal health concern (Kwak & Kim, 2018). Non-alcoholic fatty liver disease (NAFLD) affects around one-third of the population and is becoming prevalent in Western countries (Bellentani et al., 2010). Mostly brought on by fat accumulation in the liver, simple steatosis and non-alcoholic steatohepatitis (NASH) are among the many signs of non-alcoholic fatty liver disease (NAFLD). NASH can eventually result in cirrhosis, which is irreversible and can advance to hepatocellular cancer. NAFLD is therefore a risk factor for cancer, but it is also known to be a risk factor for cardiovascular illnesses (Anstee et al., 2013). Furthermore, it is currently thought that NAFLD represents the hepatic form of obesity, which is typified by diabetes type 2, insulin resistance, dyslipidemia, high blood pressure, and excess body weight (Jornayvaz & Shulman, 2012).

1.1 Levels of steatosis

Fat buildup in the liver cells is called steatosis or fatty liver. The severity of it can vary, and the amount of fat in the liver cells is usually used to evaluate the degree of steatosis. Figure 1 shows the different stages of liver disease. The following are typical steatosis levels:

Grade I: This is the least severe kind. Here, the fat builds up on the organ's exterior without affecting its functionality.

Grade II: This is a moderately severe kind that must be treated medically to keep from worsening.

Grade III: This severe case of fatty liver manifests as symptoms. Active treatments are necessary (Agrawal, 2022).

2. Models and Techniques

2.1 VGG 16

By effectively applying deep convolutional layers to analyze ultrasound pictures, VGG-16 has greatly enhanced medical imaging. With the use of this technology, intricate details such as textures, edges, and anatomical structures may be extracted, emphasizing pathological anomalies and minute changes in tissue composition. Feature extraction is crucial for thorough and precise image analysis, such as identifying liver issues. Machine learning models based on the VGG-16 characteristics may be used to identify and divide ultrasound images, improving the accuracy and effectiveness of medical treatments. VGG-16 is a helpful tool in the continuous development of automated ultrasonic image processing systems (Ismail et al., 2024).

2.2 CNN

Convolutional Neural Networks (CNNs) have revolutionized computer vision by using input photographs to learn the spatial hierarchy of features. They combine low-level information, such as edges and textures, that they perceive on deeper levels to recognize complex patterns and structures. This method may help CNNs perform very well in applications like object recognition, image categorization, and segmentation. CNNs scan input images using trained filters to produce feature maps that indicate the location and presence of certain features.

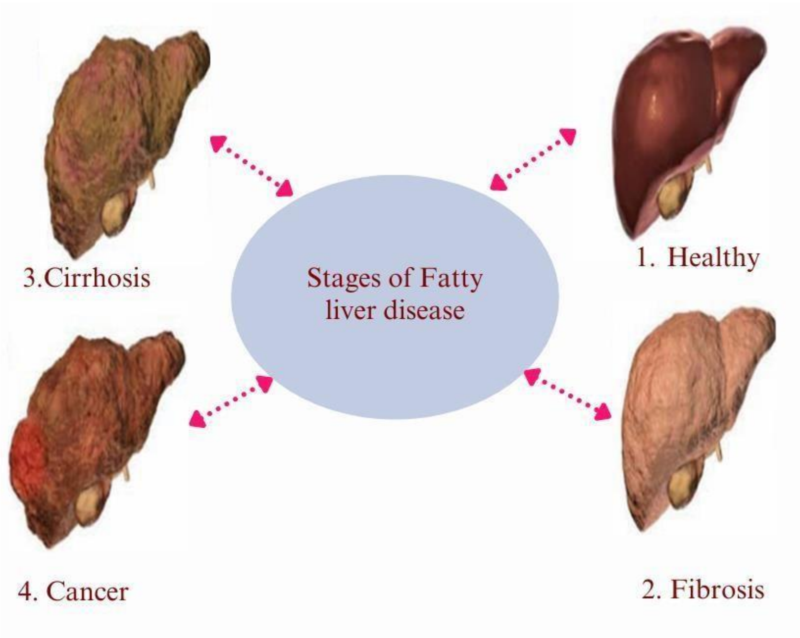


Figure 1 Different stages of fatty liver disease

Pooling layers maintain computational efficiency by shrinking the spatial dimensions of these feature maps, allowing the network to focus on the most important components. CNNs are necessary for neural network applications related to image analysis nowadays (Litjens et al., 2017).

2.3 GLCM

The liver ROIs were analysed using the same parameters as in the HI approach, but square sections with a side length of 10 mm were used in place of circular regions. For every ROI, the nine distinct GLCMs were computed, accounting for route lengths of 1, 2, and 3 as well as angles ranging from 0 to 135 and 45 to 135. Next, for every GLCM, the subsequent texture attributes were extracted: maximal probability, correlation, inverse difference, inverse difference moment, dissimilarity, contrast, homogeneity, and entropy (Clausi, 2002).

3. Literature Review

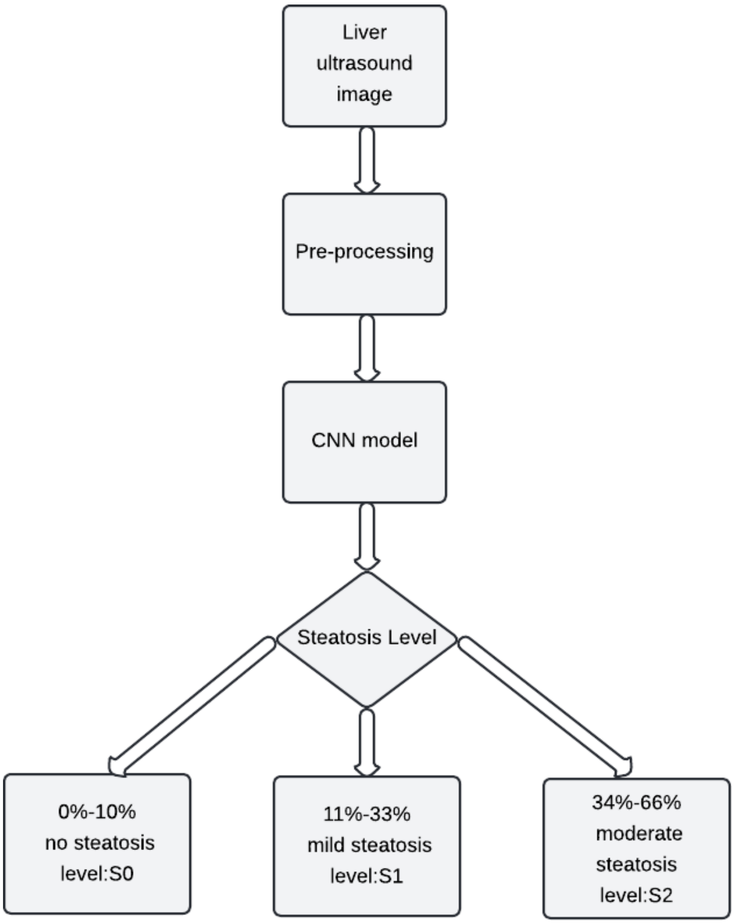
Non-alcoholic fatty liver disease (NAFLD) can be slowed down in its course with a balanced diet and regular exercise. The diet's composition isn't clearly defined, though. While monounsaturated fats, polyunsaturated PUFAs, Proteins derived from plants, and food fibres are helpful to the liver, macronutrients such as animal proteins, carbohydrates, trans fats, and saturated fatty acids can cause damage to the liver. It is less well- established how certain micronutrients affect fitness. cases with NAFLD frequently eat a Western diet high in junk food and processed foods, however, even an iso-caloric or body weight-neutral Mediterranean diet can help treat NAFLD (Malladi et al., 2023). Non-alcoholic fatty liver condition (NAFLD), the most prevalent chronic liver illness in Western nations, affects about one in three people and is currently understood to be the hepatic manifestation of the metabolic syndrome. One significant risk factor for the onset of type 2 diabetes is insulin resistance, which is closely associated with non-alcoholic fatty liver disease (NAFLD). As of yet, NAFLD patients lack access to dependable and effective pharmacotherapies. However, there is a substantial correlation between NAFLD and obesity, which is one of the primary characteristics of the metabolic syndrome. Thus, the initial treatment strategies to treat NAFLD are lifestyle changes, such as losing weight and increasing physical exercise. However, there is a substantial correlation between NAFLD and obesity, which is one of the primary characteristics of the metabolic syndrome. Thus, the initial treatment strategies to treat NAFLD are lifestyle changes, such as losing weight and increasing physical exercise. While losing weight is helpful for people with non-alcoholic fatty liver disease (NAFLD), some diets that are known to help with weight reduction can also worsen the condition and lead to insulin resistance. Examples of these diets are extremely low carbohydrate, high-fat plans. Furthermore, NAFLD can be affected by the makeup of a macronutrient diet without affecting body weight. Diets high in refined carbs, such as those in soft drinks, or saturated fats, in particular, might make NAFLD worse (Younossi et al., 2023). Using just pixels and diagnosis labels as input, convolutional neural networks (CNNs) with different topologies have been proposed for the identification of fatty liver disorders in photographs. It used a dataset of 629 images to train and test our models, which comprised pictures with liver steatosis as well as normal. It used fine-tuning to evaluate two pre-trained convolutional neural network models, Inception-v3 and VGG-16. The ImageNet collection was used to pre-train both models to extract features from B-mode ultrasonography liver pictures. The data from various methods were evaluated to select the prediction model with the best performance metrics (Constantinescu et al., 2021).

Because steatosis may lead to more severe liver disorders including non-alcoholic steatohepatitis (NASH) and cirrhosis, it is becoming more widely recognized as a serious health problem. Steatosis, also known as fatty liver disease, is characterized by the abnormal buildup of lipids in the liver. Numerous facets of steatosis have been brought to light by research, from its pathogenesis to possible treatment options (S. L. et al., 2019). Getting enough exercise is also essential for controlling steatosis. The advantages of consistent exercise in reducing the buildup of liver fat. Their research highlights exercise as a potent non-pharmacological steatosis strategy by showing that both aerobic and strength training significantly reduce liver fat (M. K. et al., 2019). Further advances in our understanding of steatosis have come from discoveries on genetic and epigenetic variables. how individual vulnerability to fatty liver disease is influenced by both genetic predispositions and epigenetic alterations. According to this study, genetic profile-based personalized preventive and therapeutic plans may improve steatosis management (R. T. et al., 2021). It discusses how dietary treatments, such as low-carb and

Mediterranean diets, may enhance metabolic health and dramatically lower liver fat. This shows that making specific dietary adjustments can effectively manage steatosis (S. L. et al., 2021). The use of pharmaceuticals to treat steatosis is also becoming more popular. It assesses different drugs that have shown promise in lowering liver fat and enhancing liver health, including those that target inflammation and insulin resistance. The evaluation recommends more investigation to figure out the long-term effectiveness and safety of these medicines despite the encouraging results (A. M. et al., 2020).

4. Proposed Method

Figure 2, shows the proposed method remedies for fatty liver patients. Evaluating and predicting the degree of fatty liver disease in liver ultrasound images requires a comprehensive method encompassing several important stages. The first step in training and validating the machine learning algorithm is compiling a set of liver imaging datasets. The images go through pre-processing, where they are scaled, normalized, and strengthened by



.Figure 2 Remedies action for fatty liver patients

augmentation, to guarantee consistency and stability in the model. This crucial step enhances the quality of the data and prepares it for a more thorough analysis. The pre-processed images are fed into a neural network consisting of a convolution (CNN) model, which is then trained and verified to reliably predict the amount of steatosis in the liver images. Well-known CNN models like ResNet, VGG, and Inception successfully analyze images. In addition to cutting-edge machine learning techniques, this method provides a workable remedy for diagnosing and treating liver steatosis.

5. Result and Discussion

Based on the proportion of fat-containing liver cells among 100 patients, a bar plot was utilized to show the distribution of steatosis levels. The distribution steatosis level is shown in Figure 3. The following is the classification of steatosis levels:

- **Grade 0 (<5%):** Absence of Steatosis (Green bar)
- **Grade 1 (5-33%):** Steatosis in mild form (Yellow bar)
- **Grade 2 (34-66%):** Steatosis in Moderation (Orange bar)
- **Grade 3 (>66%):** Extreme Steatosis (Red bar)

1. Grade 0: No Steatosis

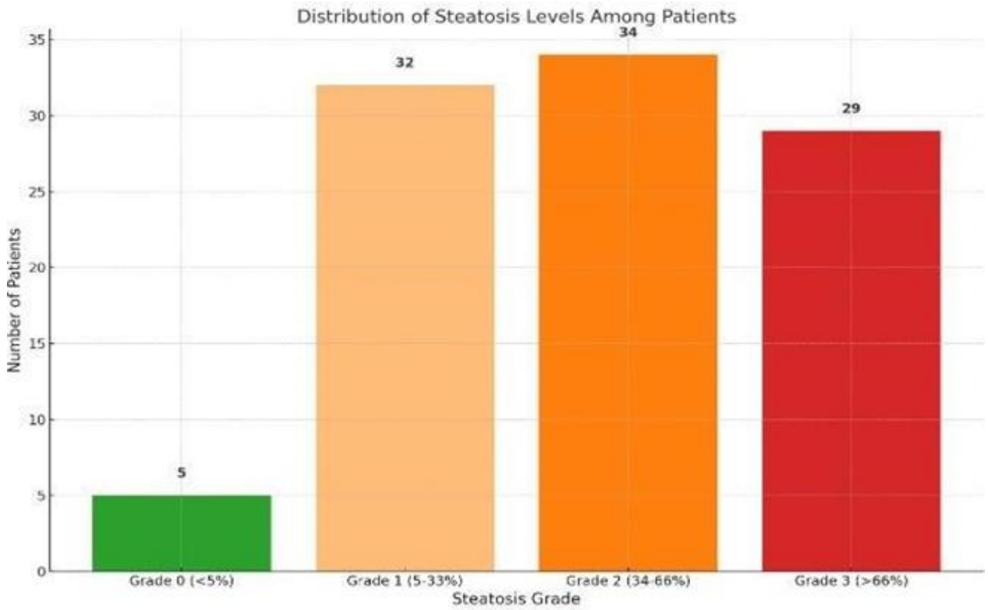


Figure 3 Distribution of steatosis levels among patients

- Less than 5% of the liver cells in five individuals had fat.
- The green bar, which shows that none of these individuals had steatosis,

2. Grade 1: Mild Steatosis

- Thirty-two patients make up this group, which is the majority.
- The yellow bar indicates that this group has moderate steatosis, with 5–33% fat in their liver cells.

3. Grade 2: Moderate Steatosis

- 34 individuals in all have moderate steatosis, meaning that 34-66% of their liver cells are fat.

- The orange bar reflects this category, which makes up a sizable share of the patient base.

4. **Grade 3: Severe Steatosis**

- Severe steatosis is present in 29 individuals, with over 66% of their liver cells being fat.
- The red bar, which shows a sizable proportion of individuals with substantial liver fat buildup, indicates this.

According to the distribution seen in the bar plot, a sizable portion of the patients had moderate to severe steatosis. Given that a sizable fraction of the population has significant fat deposition in their liver cells, this raises possible public health concerns about fatty liver disease.

Scatter Plot Analysis of Steatosis Levels

In Figure. 4 The distribution and the scatter plot show the degree of severity of the condition among the 100 cases, which offers a thorough visual representation of the steatosis levels among them.

Key Features of the Scatter Plot:

- **X-axis (Patient Index):**
- Represents each patient from 1 to 100.
- This axis allows us to identify individual patients and their respective steatosis levels.
- **Y-axis (Percentage of Liver Cells Containing Fat):**
- Shows the proportion of fat in each patient's liver cells.
- This axis offers a numerical representation of the degree of steatosis.
- **Color Coding (Steatosis Grade):**

To visually distinguish between various steatosis degrees, points are colored based on steatosis grades.

- **Grade 0 (<5%):** No steatosis, represented by dark colors.
- **Grade 1 (5-33%):** Mild steatosis.
- **Grade 2 (34-66%):** Moderate steatosis.
- **Grade 3 (>66%):** Severe steatosis, represented by bright colors.

- **Color Bar:**
- The grades are made easier to understand by a color bar on the right side of the plot, which shows the transition from no steatosis to severe steatosis.
- The contrast between the light and dark hues draws attention to how severe steatosis is.

Observations from the Scatter Plot:

1. **Spread and Clustering:**

- The distribution of steatosis levels among the patient group is shown by the scatter plot.
- It is simple to determine the concentration of patients within each grade group since individuals with comparable degrees of steatosis tend to cluster together.

2. Grade 0 (No Steatosis):

- Dark colors indicate patients whose liver cells have less than 5% fat in them.
- There are fewer patients without steatosis, as seen by the sparse distribution of these spots.

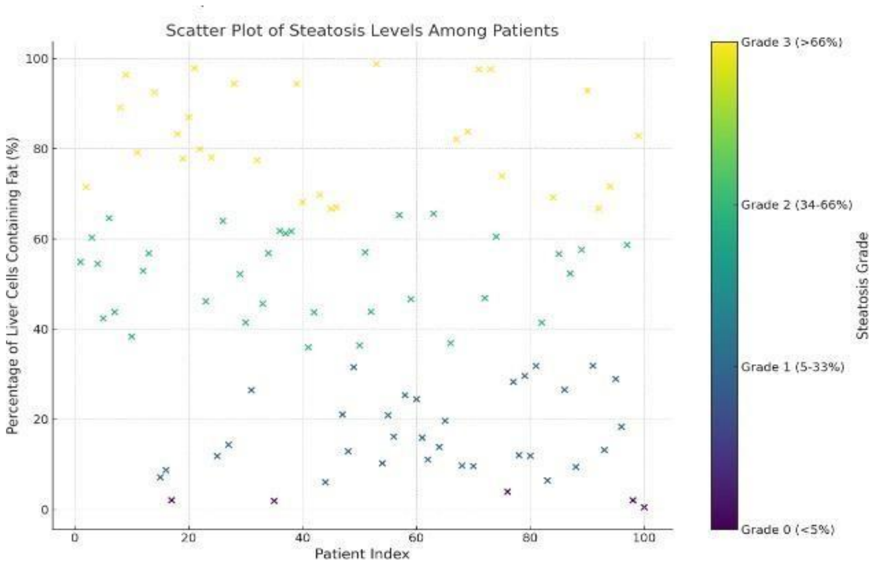


Figure 4 Steatosis levels among patients

3. Grade 1 (Mild Steatosis):

- A bigger cluster is formed by patients whose liver cells contain 5–33% fat.
- This group, which represents a sizeable fraction of the population, is well-represented and has moderate steatosis.

4. Grade 2 (Moderate Steatosis):

- The scatter plot shows a good representation of patients with 34-66% body fat.
- The frequency of mild steatosis is shown by the clustering of points in this range.

5. Grade 3 (Severe Steatosis):

- Bright colors are used to identify patients whose liver cells contain more than 66% fat.
- A sizable portion of the patients in this category had severe steatosis, which indicates a major buildup of liver fat.

Fatty liver disease, or hepatic steatosis, is characterized by the accumulation of fat in the liver. The treatment and management strategies can vary based on the level or severity of steatosis. Table 1. Shown the general guidelines and remedies tailored to different stages of fatty liver disease.

Table 1 general guidelines and remedies tailored to different stages of fatty liver disease

Stage	Lifestyle Modifications	Medical Interventions	Supplements/Natural Remedies
Grade 1 (5-33%): Mild Steatosis (Mild Fatty Liver) (Yellow bar in Figure 4)	- Reduce fat intake (avoid saturated and trans fats)	N/A	- Milk Thistle (silymarin)
	- Increase fiber (fruits, vegetables, whole grains)		- Turmeric (curcumin)
	- Limit sugar and refined carbohydrates		- Green Tea (rich in antioxidants)
	- Moderate alcohol consumption (ideally avoid)		
	- Regular physical activity (150 minutes of moderate-intensity exercise per week)		
	- Gradual weight loss if overweight (5-10% of body weight reduction)		
Grade 2 (34-66%): Non-alcoholic Steatohepatitis (NASH) (Orange bar in Figure 4)	- Intensive dietary adjustments (consult a dietitian)	- Medications (e.g., vitamin E, pioglitazone; under medical supervision)	- Omega-3 fatty acids
	- Anti-inflammatory foods (fatty fish, leafy greens, nuts)	- Supplements (e.g., omega-3 fatty acids, antioxidants; under medical supervision)	
	- Regular monitoring with the healthcare provider		
Grade 3 (>66%): Severe Steatosis (Advanced Fibrosis or Cirrhosis) (Red	- Advanced dietary management (possible protein intake restrictions)	- Close medical supervision (regular consultations with hepatologist)	
	- Monitor for malnutrition and ensure adequate nutrient intake	- Frequent liver function tests and imaging studies	
	- Complete abstinence from	- Specific treatments for complications (e.g.,	

bar in Figure 4)	alcohol	medications for portal hypertension)	
	- Avoid medications that can further damage the liver	- Liver transplant (considered in end-stage liver disease)	

Grade 1 (5-33%): Mild Steatosis (Mild Fatty Liver) (Yellow bar in Figure. 4) Lifestyle Modifications:

1. **Dietary Changes:**

o **Reduce Fat Intake:** Avoid saturated fats and Trans fats; prefer healthy fats like those found in olive oil, avocados, and nuts.

o **Increase Fiber:** Include plenty of fruits, vegetables, and whole grains.

o **Limit Sugar and Refined Carbohydrates:** Reduce intake of sugary beverages, sweets, and refined carbs like white bread and pasta.

o **Moderate Alcohol Consumption:** Ideally, avoid alcohol altogether.

2. **Exercise:**

o Engage in regular physical activity such as brisk walking, jogging, or cycling. Aim for at least 150 minutes of moderate-intensity exercise per week.

3. **Weight Management:**

o Aim for gradual weight loss if overweight. A reduction of 5-10% of body weight can significantly reduce liver fat.

Grade 2 (34-66%): Nonalcoholic Steatohepatitis (NASH) (Orange bar in Figure. 4)

NASH involves inflammation and liver cell damage, in addition to fat accumulation.

Advanced Lifestyle Modifications:

1. **Intensive Dietary Adjustments:**

o Consider consulting a dietitian to create a personalized diet plan.

o Focus on anti-inflammatory foods, such as fatty fish (rich in omega-3 fatty acids), leafy greens, and nuts.

2. **Regular Monitoring:**

o Regular check-ups with a healthcare provider to monitor liver function and progression of the disease.

3. **Medical Interventions:**

o **Medications:** Some medications, such as vitamin E and pioglitazone, might be prescribed, although their use is subject to ongoing research and should be guided by a healthcare professional.

o **Supplements:** Certain supplements like omega-3 fatty acids and antioxidants may help, but they should be taken under medical supervision.

Grade 3 (>66%): Severe Steatosis (Advanced Fibrosis or Cirrhosis) (Red bar in Figure. 4)

This stage involves significant liver damage and scarring.

Medical and Lifestyle Interventions:

1. **Close Medical Supervision:**

o Regular consultations with a hepatologist or a liver specialist.

o Frequent liver function tests and imaging studies to monitor the liver's condition.

2. **Advanced Dietary Management:**

o Possible restrictions on protein intake if liver function is severely impaired.

o Monitoring for signs of malnutrition and ensuring adequate nutrient intake.

3. **Medication and Treatment:**

o **Medications:** Specific treatments targeting complications of cirrhosis, such as medications to reduce portal hypertension.

o **Liver Transplant:** In cases of end-stage liver disease, a liver transplant might be considered.

4. **Avoidance of Hepatotoxins:**

o Complete abstinence from alcohol.

o Avoidance of medications that can further damage the liver.

General Supplements and Natural Remedies

While not substitutes for medical treatment, some supplements and natural remedies may support liver health:

1. **Milk Thistle:** Contains silymarin, which may support liver health and function.

2. **Turmeric:** Curcumin, the active ingredient, has anti-inflammatory properties that may benefit the liver.

3. **Green Tea:** Rich in antioxidants, which may help reduce liver fat.

Final Note

It's important to approach fatty liver disease with a comprehensive plan that includes lifestyle changes, medical supervision, and possibly medication. Regular monitoring and follow-up with healthcare professionals are essential to manage the condition effectively and prevent progression.

Conclusion

This study demonstrates the effectiveness of the VGG-16 approach in simulating and evaluating the efficacy of various therapies for non-alcoholic fatty liver disease (NAFLD). Using the robust characteristics of the VGG-16 convolutional neural network, this paper can analyze and understand complex patterns seen in clinical and medical imaging data with remarkable accuracy. Our findings suggest that the VGG-16 model can significantly increase the anticipated accuracy of treatment outcomes, enabling NAFLD patients to benefit from more customized and effective treatment regimens. In addition to offering early diagnosis and management, the VGG-16 technique's inclusion in the evaluation of NAFLD therapies gives clinicians an effective tool for customizing therapeutic regimens for each patient. This paper highlights the transformative potential of deep learning techniques in the realm of medical diagnosis and therapeutic optimization. Future studies should focus on expanding the dataset and include additional parameters to further increase the generalizability of the prediction models and refine them even more. Ultimately, the results of this study pave the way for more precise and effective NAFLD treatment, enhancing patient outcomes and advancing the field of hepatology.

6. **Conflict of interest -** The authors do not have any conflict of interest.

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8. **Author contribution**- Not Applicable

9. **Research Involving Human and /or Animals** - Not Applicable

10. **Informed Consent**- Not Applicable

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