Predicting Disease Progression in Cirrhosis Using Artificial Neural Networks

The GenG Model to Improve Prognostic Accuracy in Healthcare

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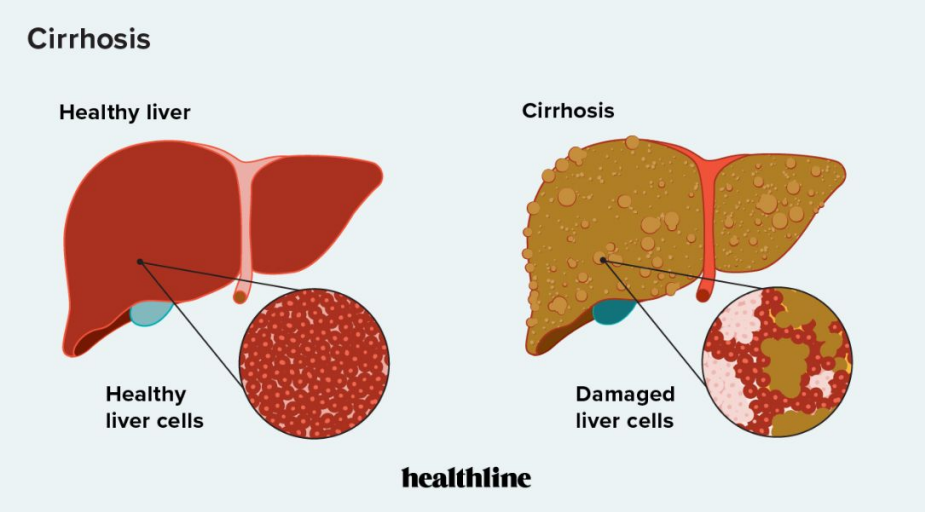


Cirrhosis – A Critical Liver Condition

- Cirrhosis is a chronic liver disease that can lead to severe complications, including liver failure and death.
- Early prediction is crucial but traditional methods can be limited by human error and difficulty in recognizing patterns in complex data.

Key Question: How can we leverage artificial intelligence, specifically an Artificial Neural Network (ANN), to enhance the accuracy of predicting cirrhosis progression?

Overview of the Dataset

The dataset we used contains detailed clinical information from a study conducted by the Mayo Clinic on 424 cirrhosis patients.

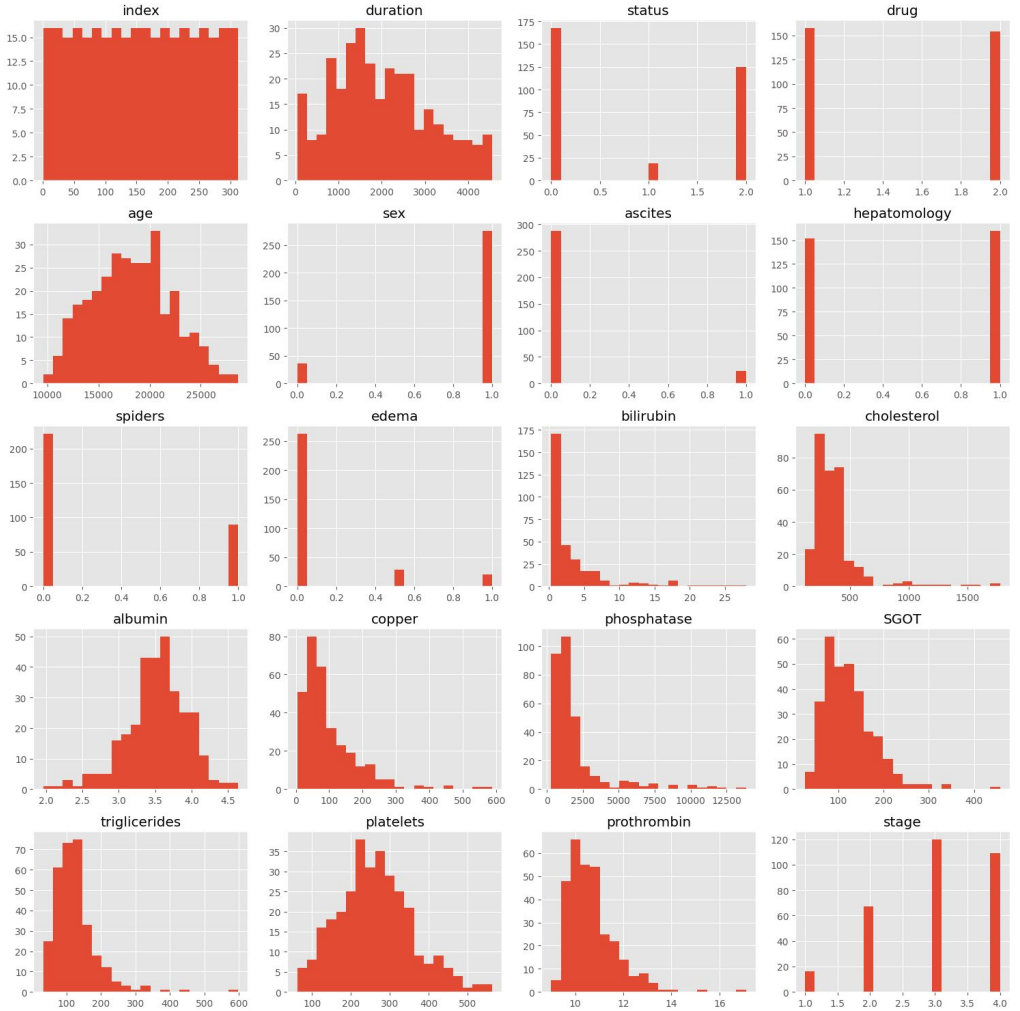
Key Variables:

- **Demographics**: Age, sex, and more.
- **Clinical observations**: Presence of ascites, hepatomegaly, spider angiomas.
- **Blood tests**: Bilirubin, cholesterol, albumin, and others.
- **Target Variable:** The histological stage of cirrhosis, with four stages representing disease progression.

A Brief Exploratory Data Analysis (EDA)

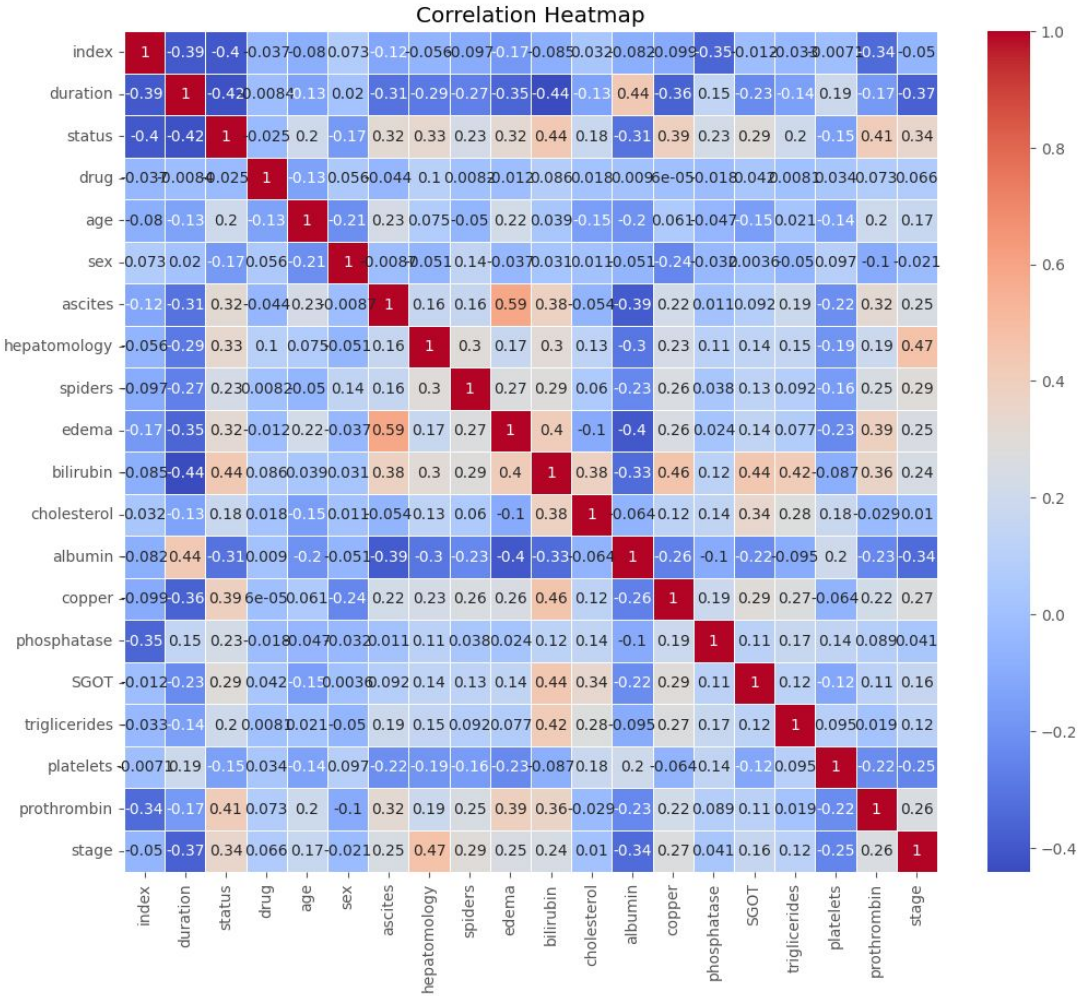
Distribution of Features

- **Most of the features are skewed and have non-normal distributions, indicating that transformations (such as normalization or log transformations) might be necessary for machine learning models.**
- **The "stage" column, which is the target for prediction, shows a clear multi-class nature with four stages of cirrhosis.**

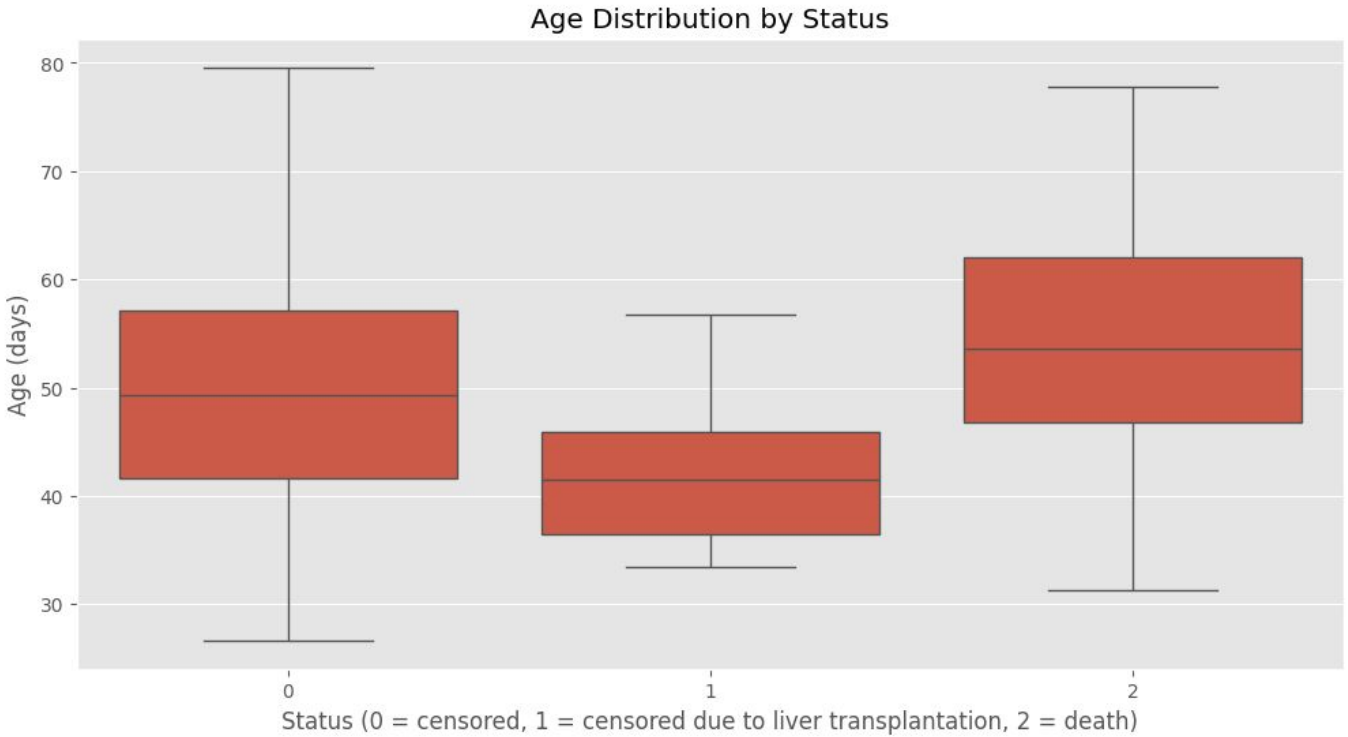


Correlation of Features

- **Multicollinearity: Some variables like edema and ascites are highly correlated, which might introduce multicollinearity issues if used together in certain machine learning models.**
- **Feature Selection: Variables with stronger correlations to the target (stage), such as hepatomegaly, bilirubin, and albumin, are likely important predictors for the stage of cirrhosis.**



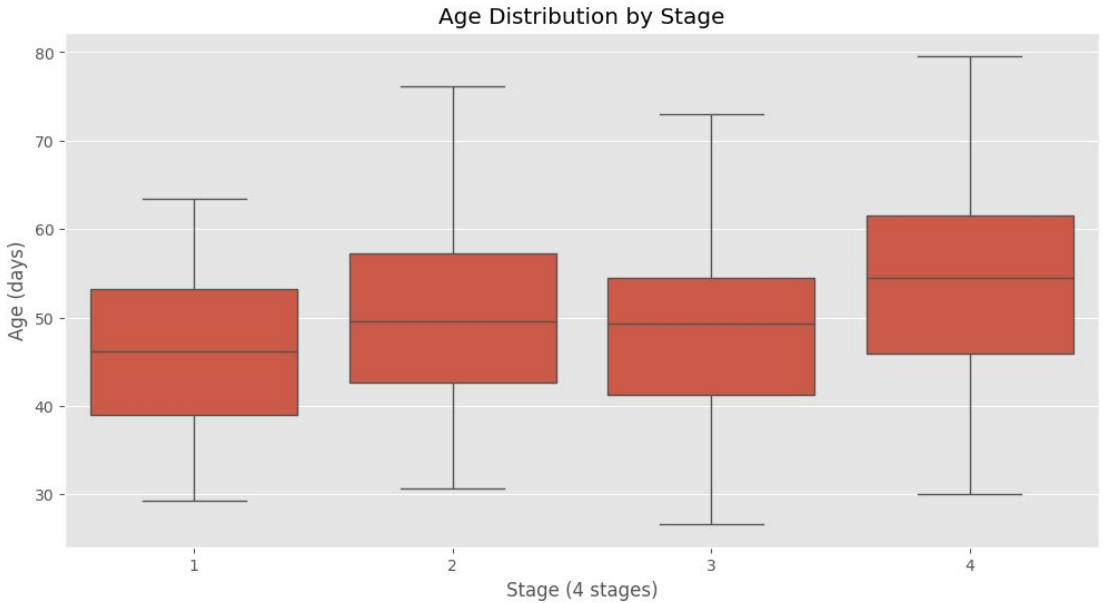
Age and Status



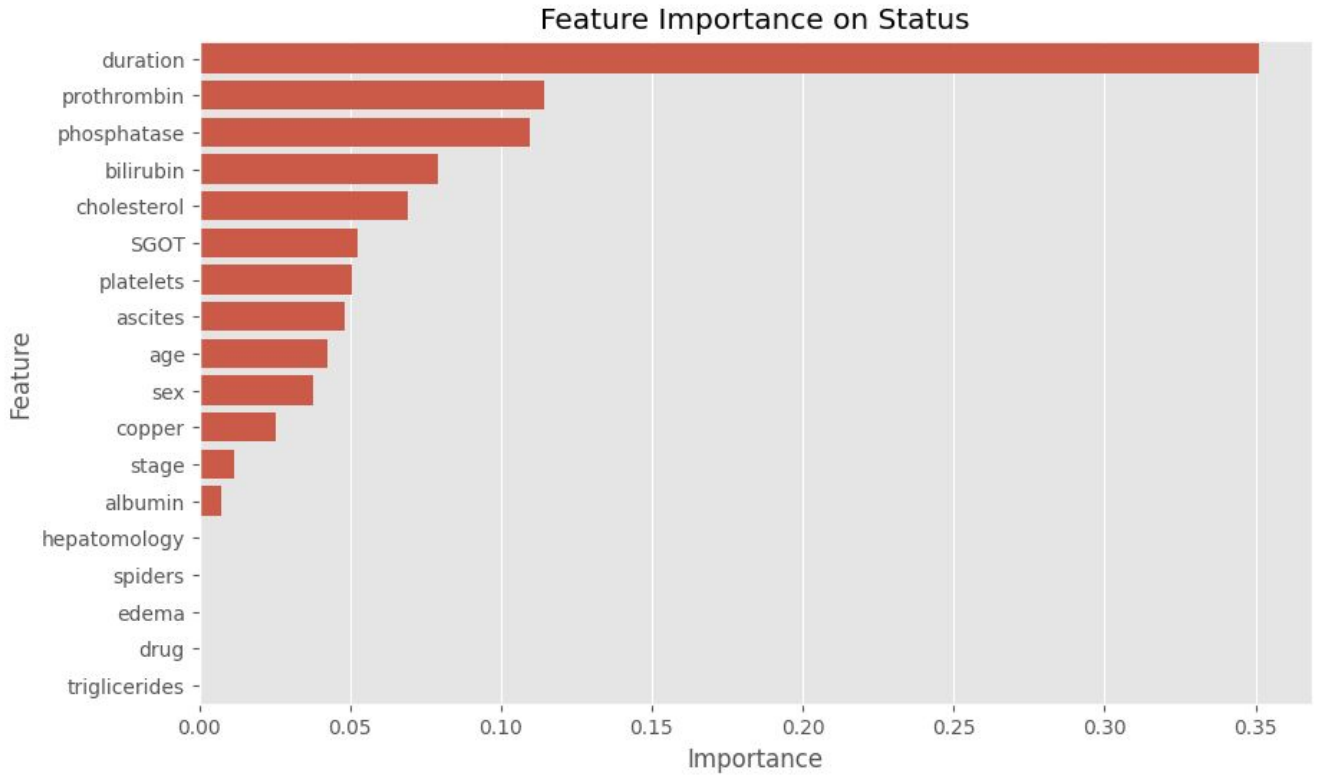
- **Patients who underwent liver transplants (status 1) are generally younger compared to the other groups.**
- **Patients who are censored or have passed away have similar age distributions, but there is more variability in the "death" group.**

Age and Stage

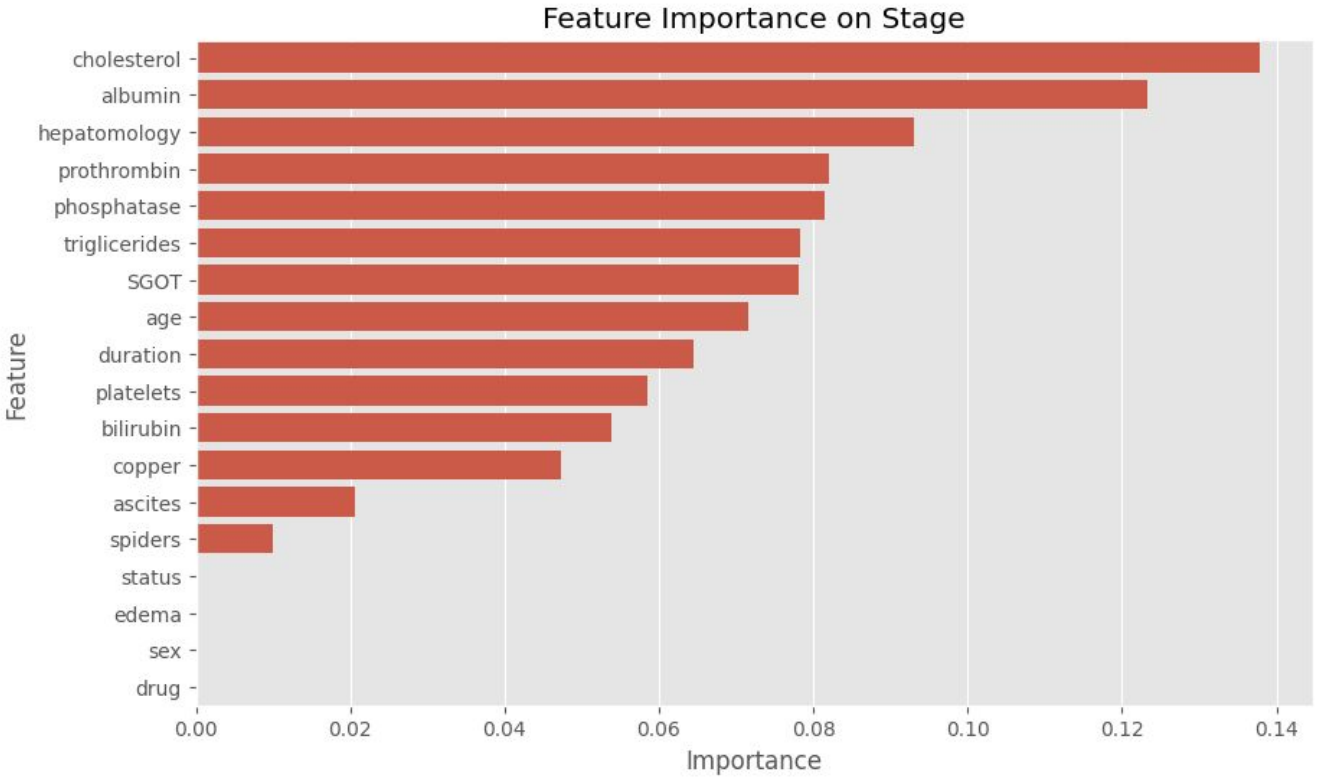
- **Across all stages, the median age is relatively consistent (around 45–50 days), but the variability in age increases as the disease progresses to more advanced stages (especially in Stages 3 and 4).**
- **Stage 4 shows the greatest spread in age, suggesting that patients in more advanced stages of cirrhosis span a wide age range, whereas Stage 1 is more concentrated in a specific age group.**



Feature Importance Analysis



Feature Importance Analysis



Artificial Neural Network (ANN)

Overview

What is ANN?

An **Artificial Neural Network** mimics the brain's neurons and connections to identify patterns in data. It's particularly powerful for **nonlinear, complex relationships** like those in medical data.

Our Model:

- We designed an ANN with 2 hidden layers:
  - **64 neurons** in the first layer and **32 neurons** in the second layer.
  - **Activation Function**: ReLU (Rectified Linear Unit) for the hidden layers to handle non-linearities in the data.
  - **Output Layer**: Uses **softmax** activation for multi-class classification to predict the disease stage (4 stages).

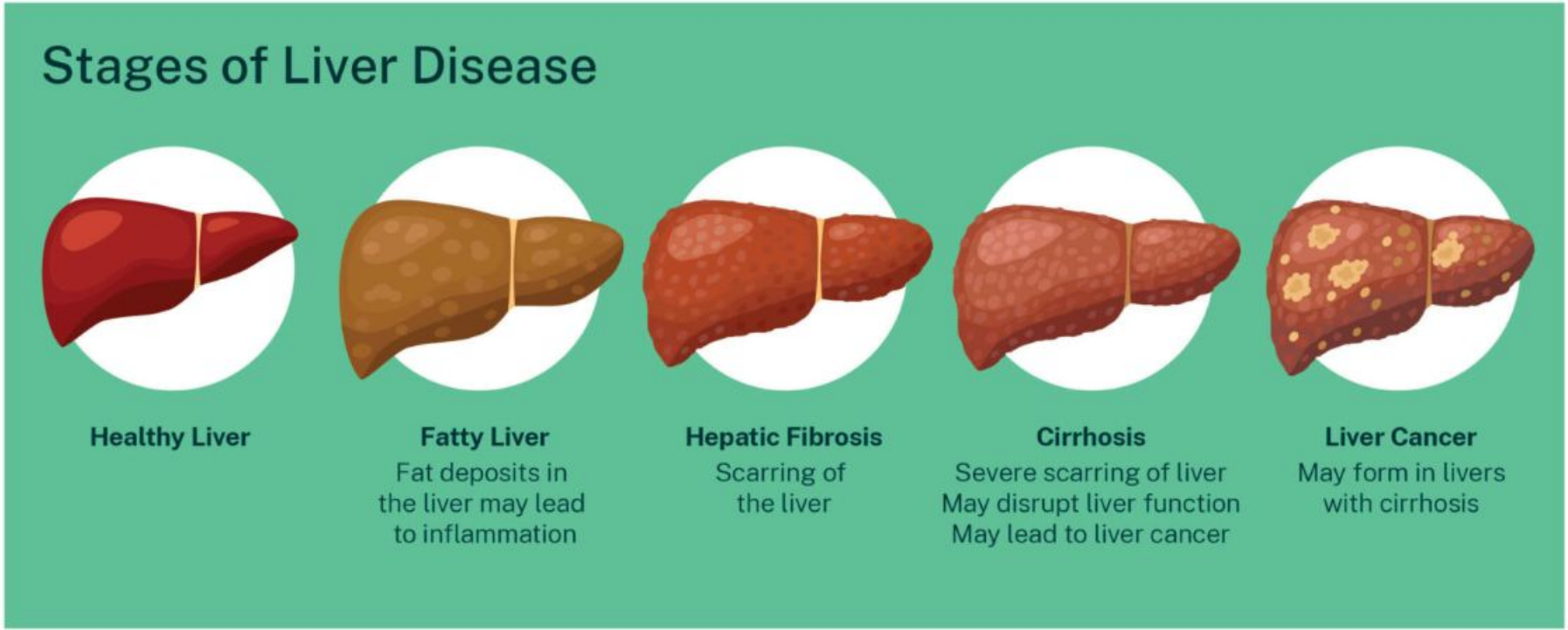
Training the Model

We trained the ANN on features such as **bilirubin, albumin, age, prothrombin time, cholesterol**, and more, with the goal of predicting the **stage of cirrhosis**.

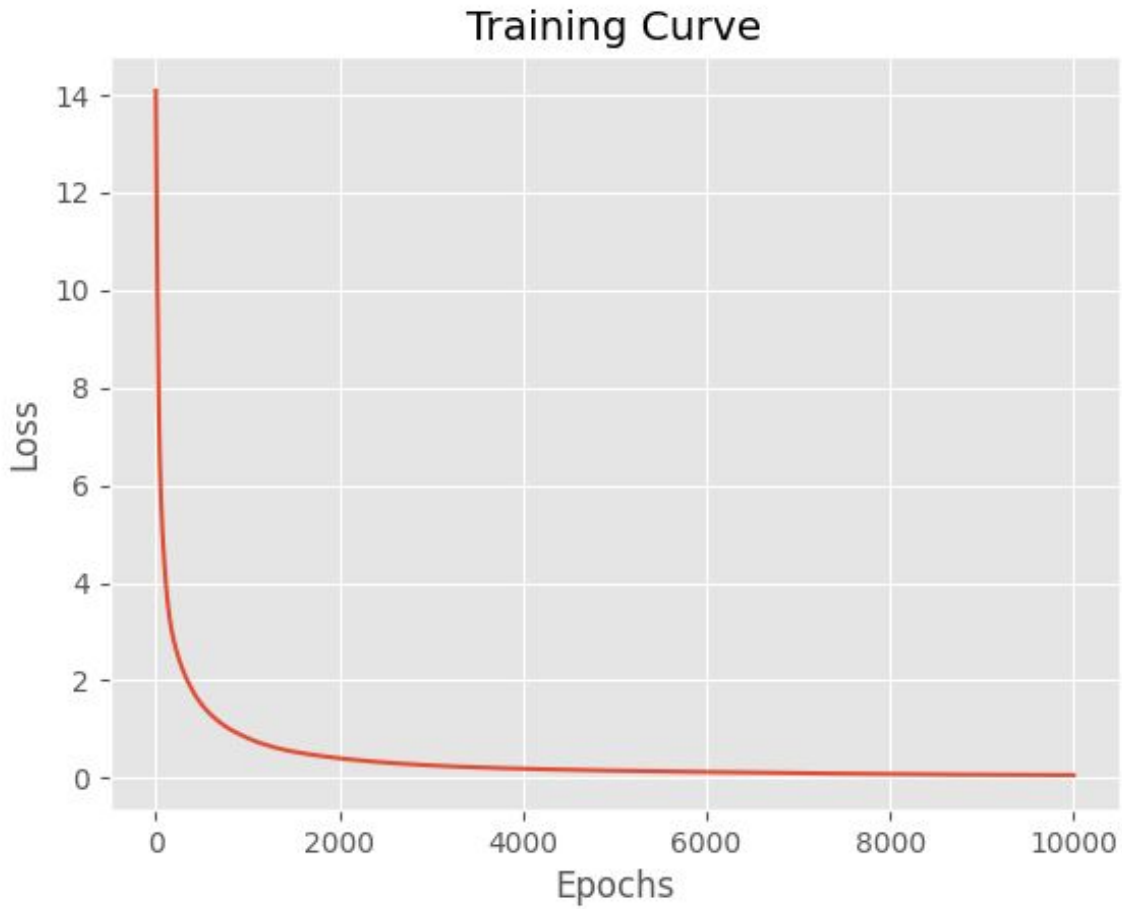
Process:

- Data was **standardized** using scaling to ensure all features were on a comparable range.
- The model was trained for **10,000 epochs** with a learning rate of 0.001 to optimize the prediction accuracy.
- **Loss function**: Cross-entropy was used to penalize incorrect predictions and guide the learning process.
- The ANN achieved a strong performance with an overall accuracy of more than 80% on the training set.

Predicting the Stages of Cirrhosis



Training Curve



The real world application of the model

For Doctors:

- The ANN model can act as a **decision support tool**, providing an initial stage prediction. The doctor can use this prediction as a starting point and perform a **final review** to confirm the diagnosis.
- This reduces the time spent on diagnosis while still allowing the physician to maintain full control over the final outcome.

For Scientists:

- This method blends the strengths of AI in analyzing vast amounts of data with the **human insight** of experienced healthcare professionals.
- Doctors remain integral to the diagnostic process, especially for rare or borderline cases where their expertise can identify nuances the model may miss.

Traditional Clinical Process vs. ANN Model Application

Aspect	Traditional Process	ANN Model with Doctor QA
Steps Involved	Clinical exams, blood tests, imaging, biopsy, lab analysis	Blood test → ANN prediction → Doctor confirmation
Time to Diagnosis	Several days to a week (biopsy + imaging delay)	Minutes to hours (blood test + model + doctor review)
Resources Required	Doctor consultations, multiple lab tests, imaging, biopsy	Blood test, ANN model, brief doctor review
Accuracy	High, but subject to human error in biopsy interpretation	Near 100% with model prediction and doctor confirmation
Invasiveness	Biopsy (invasive, with risk)	Non-invasive blood test
Risk to Patient	Moderate (biopsy risks)	Low (non-invasive)

Traditional Clinical Process vs. ANN Model Application

Traditional Approach: Patient A undergoes blood tests, imaging, and a biopsy. Diagnosis takes **5-7 days**.
ANN Approach with Doctor QA:

- Patient A's blood test results are fed into the model.
- **Model Prediction**: Within minutes, the model predicts that the patient is in Stage 3 of cirrhosis.
- **Doctor Confirmation**: A doctor reviews the model's output, confirms that the prediction is accurate based on additional clinical signs or tests.
- **Total Time**: 30 minutes to a few hours (depending on the availability of the doctor for final review).

Cost Comparison: Traditional vs. ANN Model

Aspect	Traditional Clinical Process	ANN Model with Doctor QA
Doctor Consultations	$200 - $300 per consultation (multiple consultations)	$100 for model validation consultation
Blood Tests	$100 - $200 (multiple tests)	$100 (standard blood panel)
Imaging (Ultrasound/CT/MRI)	$500 - $2,000	$0 (not needed for most cases)
Liver Biopsy	$3,000 - $5,000 (procedure + pathology analysis)	$0 (non-invasive diagnosis with model)
Hospital or Lab Visit Costs	$500 - $1,500 (multiple visits)	$0 (single blood test visit)
Total Estimated Cost	**$4,300 - $9,000 per patient**	**$200 - $300 per patient**

Cost Comparison: Traditional vs. ANN Model

Reduced Procedure Costs: Eliminating invasive and expensive procedures like biopsies saves thousands of dollars per patient.
Less Doctor Time Required: Doctors can focus on reviewing and confirming predictions, which reduces consultation time, ultimately lowering the costs of medical labor.
Faster Results, Fewer Visits: Patients don't need to return for multiple appointments or lab visits, reducing associated costs of hospital stays or transportation.
Scalability: Once deployed, the model can be used for **thousands of patients** with minimal additional cost, drastically lowering the **per-patient cost** for healthcare providers.

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ANN Model

Key Benefits

Estimated Time Saving per Patient:

5 - 7 days

Estimated Cost Saving per Patient:

USD 4’000 to USD 6’000

Final Words

- **Hybrid Approach**: The ANN model acts as a rapid initial screening tool, but the final stage diagnosis is always confirmed by a healthcare professional. This ensures the **highest level of accuracy** while greatly reducing the time and resources needed for diagnosis.
- **Benefits**: By combining AI with human expertise, we:
  - Reduce diagnostic times from days to minutes.
  - Maintain **100% confidence** in the results through **doctor validation**.
  - Improve patient outcomes with **faster, more accurate decisions**.

This hybrid approach offers the **best of both worlds**—AI's speed and precision, with the reliability and insight of medical expertise.

Thank You