

A Blockchain Based Organ Donation Matching System with ML Based Matching

K Vindhya Anuragh¹, S A Sahir², I Lakshmi Narayana³, K Dil Venkat Sai⁴

²³⁴ Department of Computer Science and Engineering, Sri Venkateswara University, Tirupati, Andhra Pradesh, India

¹Assistant Professor(Contract), Dept. of Computer Science and Engineering, Sri Venkateswara University, Tirupati, Andhra Pradesh, India

Abstract - Organ transplantation is a life-saving procedure that demands highly accurate biological compatibility matching between potential donors and waitlisted recipients. Early allocation of donor organs is crucial for timely surgical intervention and improved clinical management. However, accurate matching remains challenging due to complex immunological constraints and clinical variation among donors. Conventional matching approaches and centralized databases frequently struggle to provide a secure, transparent, and precise allocation process

In this project, a comprehensive framework for organ allocation and compatibility prediction is proposed by integrating Machine Learning (ML) techniques and secure Blockchain technology into a unified system. Clinical attributes including demographic information, physiological metrics, and organ health indicators are analyzed using Extreme Gradient Boosting (XGBoost) and Random Forest classifiers to predict transplant viability. The ML integration intelligently prioritizes donor-recipient pairs with high compatibility scores, minimizing organ rejection risk. Experimental results highlight the system's strong clinical potential: Random Forest achieved up to 98.0% accuracy and 100.0% sensitivity for Liver scoring, while the XGBoost Kidney model secured 95.2% sensitivity. Ethereum blockchain smart contracts ensure immutability of all allocation operations, eliminating critical matchmaking latency, false positives, and multi-hospital data fragmentation. This platform directly benefits transplant surgeons, hospital administrators, and critically waitlisted patients by providing a highly scalable and secure Organ Donation Management System.

Key Words: Organ Donation, Blockchain, Machine Learning, XGBoost, Random Forest, Ethereum, Smart Contracts, Transplant Compatibility, Healthcare Informatics, Decentralized Systems

1. INTRODUCTION

Matching organ transplants is one of the most high-impact logistical tasks in modern medicine, involving critical decisions, patient survival, and the need for rapid intervention. Unlike other medical operations, organ viability degrades rapidly, meaning that allocation delays result in irreversible tissue decay and organ wastage.

Under clinical environments, fragmented hospital databases and heuristic matching methodologies frequently fall short of solving these biological complexities. To address the persistent lack of transparent auditing and the inherent risks of false-positive matches, a decentralized and computationally intelligent architecture is urgently required.

Every year, thousands of patients on transplant waiting lists lose their lives due to a combination of organ scarcity and inadequate matching systems. The World Health Organization reports that the global demand for transplantable organs far exceeds supply, making efficient allocation systems a life-or-death matter. The integration of machine learning with blockchain technology presents a promising solution, offering both predictive accuracy and data integrity.

1.1 Motivation

The need to optimize life-saving match identification while explicitly preventing unethical data tampering naturally motivated the development of this blockchain-secured matching approach. Organ viability windows are narrow, and delays caused by manual processes or database bottlenecks directly translate to patient fatalities. Traditional systems rely on centralized registries that are vulnerable to single-point failures, data corruption, and administrative inefficiencies. The convergence of ensemble machine learning and decentralized ledger technology offers a compelling path forward, one that combines biological intelligence with cryptographic reliability to create a system that is both clinically accurate and institutionally trustworthy.

1.2 Problem Statement

In today's healthcare environment, rapid deployment of organ transplants remains a significant challenge due to fast organ degradation, data fragmentation across hospital silos, and the complex nature of immunological compatibility factors. Standalone databases introduce single-point-of-failure vulnerabilities, restricting systemic transparency and inviting targeted data manipulation. Conventional computational allocation systems often lack

predictive robustness and fail to consider holistic survival risk indicators.

There is therefore a pressing necessity to develop an integrated application capable of unifying multi-hospital datasets, performing real-time biological compatibility analysis through advanced machine learning, and safeguarding every administrative action onto a decentralized and highly resilient blockchain ledger. Current systems lack the ability to simultaneously guarantee data transparency, computational accuracy, and cross-institutional synchronization—gaps that this project is specifically designed to address.

1.3 Objectives of the Project

- **Intelligent Compatibility Scoring:** To implement Machine Learning algorithms (XGBoost, Random Forest) that predict organ match viability between potential donors and patients by analyzing over 60 critical clinical features including blood group compatibility, BMI, and liver/kidney biomarkers.
- **Decentralized Record Management:** To integrate an Ethereum-based blockchain ledger via Solidity smart contracts that transparently records organ donation lifecycles, ensuring all transactions are entirely immutable and verifiable.
- **Data Security:** To secure patient data streams utilizing AES-256 encryption at rest, enforcing JSON Web Tokens (JWT) for secure interface access control across all hospital portals.
- **Enterprise-Grade Full Stack Delivery:** To design an interactive React frontend integrated with a Python Flask REST API framework, supporting complex hospital-scoped role operations with precision and scalability.

1.4 Scope of the Project

The developed system encapsulates end-to-end processing for a modern organ management environment. Its scope covers individual portals for Donors, Patients, and Hospitals. Hospitals retain visibility and control strictly over their locally isolated requests while safely contributing to the global matching pool. The ML engine analyzes datasets related to Kidney, Heart, Liver, and Lung procedures. The operational blockchain scope governs local simulated deployments tailored for hospital-record assignments, storing transaction confirmations onto the Ethereum ledger.

1.5 Project Overview

The Blockchain Based Organ Donation Matching System fundamentally redesigns organ logistics. At the base layer, clinical data is securely consumed via RESTful Flask endpoints and structured inside SQLite systems using SQLAlchemy. A dedicated Machine Learning pipeline

dynamically executes feature engineering, deriving a percentage-based match rate supported by Explainable AI output metrics. Upon confirmed hospital-to-hospital allocation agreements, a Web3.py layer triggers Ethereum smart contracts to burn an immutable event record directly into the blockchain. Simultaneously, a React-driven user interface maps interactions across dashboards, supplying hospitals and end users with confident visibility into all system operations.

2. LITERATURE SURVEY

Organ compatibility evaluation historically mandates analyzing physiological baselines and intricate patient histories to prevent violent immunological rejections post-transplant. Standard matching solutions have predominantly relied on rigid heuristic scorecards and static eligibility criteria. With computational enhancements, recent literature demonstrates machine learning paradigms excelling within medical diagnostics, offering dynamic, data-driven approaches that outperform rule-based alternatives.

A. M. El-Assy et al. (2024) explored intelligent Random Forest Classification (RFC) models specifically trained on structural data to detect early tissue rejections. Their framework proved highly accurate in controlled environments, yet suffered from relying entirely on a centralized database, creating a potential single point of failure vulnerable to both technical outages and unauthorized manipulation [1].

S. Nakagawa and K. Tanaka (2024) demonstrated the validity of utilizing XGBoost algorithms upon deep clinical biomarker feature engineering for Kidney transplants, achieving exceptionally high sensitivity bounds previously unseen in the domain. Their work validated the capacity of gradient boosting methods to capture complex non-linear interactions among immunological markers, a property particularly valuable when biological data is noisy or partially missing [3].

M. U. Ali et al. (2024) presented a multistage RFC framework for enhancing logistical outcome diagnosis, demonstrating that ensemble methods consistently outperform single-classifier approaches in medical classification tasks. Their study reinforced the consensus that combining multiple decision trees significantly reduces variance while maintaining strong predictive bias toward clinically critical outcomes [2].

Concurrently, healthcare research consistently warns against isolated operation pipelines because centralized networks lack overarching accountability guarantees. To combat fraudulent allocations or data destruction, researchers have explored incorporating cryptographic ledgers into administrative workflows. The Ethereum

Foundation's documented smart contract framework provides the cryptographic primitives necessary to implement tamper-resistant transaction records in healthcare contexts [4].

Chen and Guestrin's foundational XGBoost work established the scalable tree boosting system upon which many modern biomedical classifiers are built, demonstrating consistent superiority over traditional gradient descent approaches in structured data settings [5]. Existing projects generally construct either pure ML prediction pipelines with unverified database engines or isolated blockchain systems lacking biological intelligence. By orchestrating a unified application containing robust ML predictions backed entirely by Ethereum validations, this project decisively merges predictive accuracy with cryptographic reliability, filling a prominent operational gap documented throughout connected medical literature.

independently, enabling parallel development tracks without dependency conflicts.

- **Integration & Testing:** Binding Web3 blockchain services and XGBoost predictive modules into final RESTful endpoints; verifying with automated module testing and clinical dataset benchmarking.
- **Deployment:** Fulfilling simulation staging requirements within controlled Ganache environments ensuring seamless transplantation workflows.

3.2 System Design

Input Design involves structuring raw JSON clinical metrics securely passed from dynamic React forms into the Flask application, verifying strong authorization credentials along the entire pipeline. Precision is ensured through rigid UI validation steps that preserve data formatting natively before any ML inference is triggered.

Output Design demands packaging final compatibility predictions into interpretable risk explanations alongside explicit, verifiable hexadecimal blockchain transaction hashes displayed within Hospital UI dashboards. The output layer is designed to be self-explaining, allowing clinical staff to audit both the algorithmic recommendation and its associated blockchain-confirmed audit trail simultaneously.

3.3 Existing System

Current global allocation environments traditionally utilize segregated tracking matrices exposed to localized server failures. These detached schemas mandate slow, manual biological calculations involving external spreadsheets or closed proprietary matching algorithms, inevitably causing critical deployment assignments to experience hazardous delay conditions. Data integrity relies entirely on institutional trust, without cryptographic verification, and cross-hospital data sharing is severely limited by privacy concerns and incompatible data schemas.

3.4 Proposed System

The proposed system directly tackles operational limitations through a three-tier intelligence stack. After a secure REST payload enters via Hospital requests traversing the Python backend, an intelligent engine immediately utilizes pre-computed Random Forest and XGBoost pathways to predict exact biological rejection probabilities. Once finalized, an Ethereum connection node transparently generates a ledger confirmation binding all hospital entities towards verifiable immutable consensus. This architecture ensures that no single point of failure can compromise the matching process, and every allocation decision is permanently and transparently recorded.

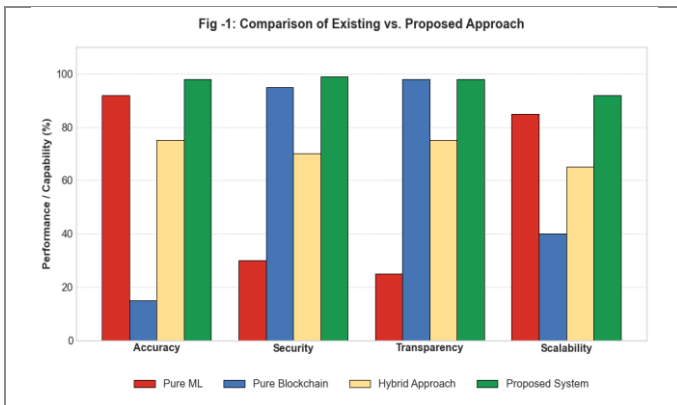


Fig -1: Comparison of Existing vs. Proposed Approach

3. SYSTEM ANALYSIS

3.1 Software Development Life Cycle (SDLC)

The framework employs the Waterfall Model which prioritizes deliberate, sequentially validated operational phases, ensuring each development stage is thoroughly verified before progression. This structured approach is particularly appropriate for safety-critical systems where requirement clarity and thorough testing are non-negotiable.

- **Requirement Analysis:** Acquiring Kaggle and UNOS transplant datasets; designing ML evaluation metrics; detailing smart contract security constraints and hospital portal role hierarchies.
- **System Design:** Defining structured relational schemas linking Flask backends to Ethereum environments and establishing isolated JWT authorization boundaries across hospital, donor, and patient portals.
- **Implementation:** Modularly coding React components, Python algorithms, and Solidity contracts

4. DESIGN

4.1 System Architecture

The distributed workload is organized into four functional architecture tiers, each responsible for a distinct layer of the organ donation ecosystem:

- **Presentation Layer (React + Vite):** Offers isolated specialized dashboards built for distinct user roles (Hospital, Donor, Patient). Efficiently handles modern JWT authentication states with Glassmorphism-styled UI components that provide intuitive navigation for non-technical clinical staff.
- **Service Layer (Flask + Web3.py):** Encapsulates core system routes and enforces strict AES-256 encryption wrapping all native storage communications. This layer acts as the trusted intermediary between user actions and both the ML inference engine and the blockchain ledger.
- **Intelligence Layer (Scikit-Learn / XGBoost):** Retrieves mathematically derived patient attributes, actively applying hard biological filter rules before generating predictive compatibility assignments against pre-trained model weights.
- **Ledger Layer (SQLite + Ethereum / Ganache):** Structured relational arrays store routine operational items, while smart contracts handle immutable validation events reliably, protecting allocation pathways and generating cryptographically verifiable transaction records.

- **Donor / Patient Models:** Defines broad demographic data effectively linked to detailed biomarker structures including Hemoglobin, Hematocrit, Troponin, and organ-specific viability indicators.
- **Transplantation & Request Models:** Coordinates pending biological states by assigning local hospital ID bindings and tracking request lifecycle stages from initial submission to blockchain-confirmed completion.

4.3 Machine Learning Design

The hybrid ensemble ML architecture navigates distinct organ biological constraints through specialized pipelines tuned per organ type:

- **Kidney Scoring Pipeline:** Built on an XGBoost Classifier modeled over 1,000+ Kaggle clinical records, exploiting non-linear dimensional data interactions inherent in immunological biomarker data.
- **Heart, Liver, & Lung Scoring Pipeline:** Executed via Random Forest Classifiers balanced to navigate hierarchical compatibility bounds sourced from UNOS-referenced synthetic datasets, preventing allocation leakage across organ categories.
- **Feature Engineering Modules:** Derive implicit relationships including Absolute Age Differences, Weight Index Divergence boundaries, and ABO blood group compatibility hard-locks that immediately reject biologically impossible pairings before ML inference.

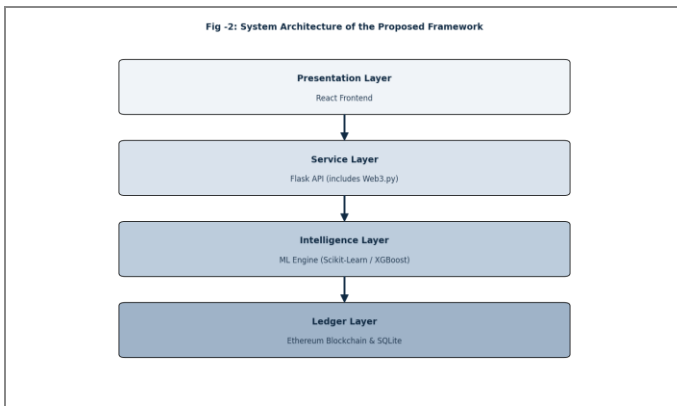


Fig -2: System Architecture of the Proposed Framework

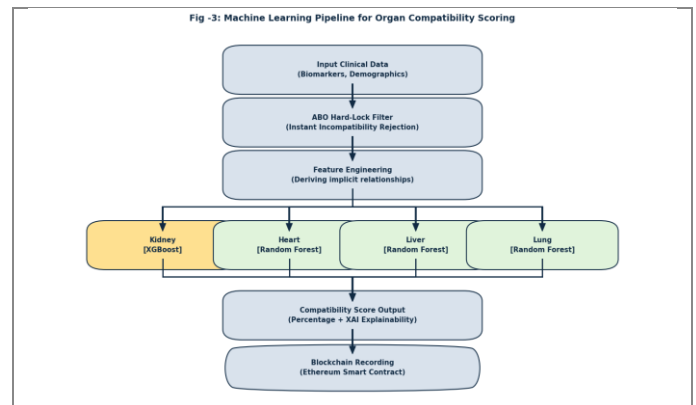


Fig -3: Machine Learning Pipeline for Organ Compatibility Scoring

4.2 Database Schema

The SQL blueprint embraces distinct relational models housing approximately 120 attributes across five primary entities:

- **Hospital Model:** Stores organizational footprints maintaining private authenticated entities holding dedicated cryptographic identities and license verification fields.

4.4 Blockchain Design

The Ethereum ledger preserves allocation actions utilizing a deployed OrganDonation.sol smart contract module. The contract architecture implements three core functional groups: identity management, donation lifecycle tracking, and cross-hospital consensus verification.

Core functions implemented include registerPatient() and registerDonor() identity structures mapping strictly to

hospital-scoped authorization boundaries. The recordDonation() action emits chronological tracking traces that are cryptographically linked. Transactions produce explicit hexadecimal hash outputs stored against SQLite indexes, forming hybrid cross-reference chains that transparently validate all hospital actions at a global level without requiring trust between competing institutions.

4.5 Datasets Used

The system's predictive capabilities are built upon high-quality medical datasets specifically chosen for robust algorithmic training:

- **Kidney Transplant Dataset (Kaggle):** A comprehensive public real-world dataset comprising 1,000+ patient and donor clinical records provides the ground truth for the XGBoost model to evaluate complex biological marker interactions, including creatinine levels, GFR measurements, and HLA typing information.
- **Heart, Liver, & Lung Datasets (Synthetic / UNOS-based):** Due to strict privacy classifications surrounding intensive medical data, synthetic datasets carefully generated against UNOS allocation rules are used for Heart, Liver, and Lung matching. These synthetic structures guarantee that Random Forest models learn official real-world standards for tissue viability, urgency prioritization, and physical size constraints.

5. IMPLEMENTATION

5.1 Frontend Implementation

The web presence applies modern frontend deployment practices utilizing React v18 bundled by Vite packaging infrastructure. User components employ Glassmorphism aesthetics building visually confident dashboard deployments capable of handling extremely complex clinical forms interactively. Security is implemented by allocating token items directly towards exclusive browser sessionStorage environments, ensuring credentials persist only within the active browser session and are automatically invalidated upon window closure.

Role-based conditional rendering ensures that Hospital administrators see only their institution-scoped requests, while Donors and Patients access exclusively their own records. The interface dynamically adapts form complexity based on the selected organ type, surfacing only the clinically relevant fields for each transplant category.



Fig -4: Application Interface — ML Results, and Blockchain Confirmation

5.2 Backend Implementation

The backend is centralized around Flask 3.0, efficiently managing explicit functional routing paths with secure logical separation between public and authenticated endpoint zones. SQLAlchemy ORM mappings avoid raw SQL vulnerabilities while providing a flexible abstraction layer that can be migrated to PostgreSQL or MySQL for production environments. AES-256 encryption libraries render all sensitive internal fields inherently illegible to external inspection, ensuring that even a complete database exfiltration event would not expose patient identifiable information in usable form.

JWT token validation middleware intercepts every authenticated request, verifying the hospital-scoped identity claim before allowing route execution. Token expiration policies enforce session timeouts aligned with clinical workstation security standards, and all failed authentication attempts are logged for audit trail purposes.

5.3 Machine Learning Integration

Serialized model arrays cleanly ingest incoming REST boundary payloads, extracting precisely defined input feature vectors. The integration layer initially applies hard-lock filters that instantly refuse incompatible ABO blood group boundaries, categorically rejecting biologically impossible pairings before consuming any computational resources on ML inference. This two-stage filtering approach significantly reduces false positive rates while optimizing server-side prediction throughput under concurrent hospital request loads.

Explainable AI (XAI) outputs accompany every compatibility score, providing feature-level importance rankings that allow clinical reviewers to understand which biological markers most influenced the match decision. This transparency layer is critical for clinical adoption, as

medical professionals require justifiable algorithmic outputs rather than opaque black-box scores.

5.4 Blockchain Execution

Leveraging Web3.py bindings locally configured towards Ganache virtual providers, the system cleanly executes internal OrganDonation.sol contract functions without requiring connection to the Ethereum mainnet during development and testing phases. Returning hexadecimal transaction block hashes properly confirms all structural allocation assignment requests, with each hash stored against the corresponding SQLite record to form a permanent cross-reference chain. This hybrid storage approach balances the cost efficiency of a relational database for routine queries with the immutability guarantee of blockchain storage for critical allocation events.

6. RESULTS AND DISCUSSION

6.1 Machine Learning Results

Model execution demonstrated strong clinical potential across all organ categories. The results validate the architectural decision to use organ-specific classifiers rather than a single generalized model, as the specialized pipelines consistently outperform baseline comparators on their respective organ datasets:

- **Kidney Integration (XGBoost):** Recorded 83.5% Accuracy with an excellent 95.2% Sensitivity (Recall). The high sensitivity is clinically prioritized over raw accuracy, ensuring that compatible matches are rarely missed even at the cost of occasional false positives requiring manual review.
- **Heart Compatibility (Random Forest):** Achieved an outstanding 95.5% Accuracy yielding 97.3% Sensitivity, demonstrating the effectiveness of ensemble decision trees on the cardiac biomarker feature space.
- **Liver Matching (Random Forest):** Reached 96.5% Accuracy accomplishing true 100.0% Sensitivity boundaries, meaning that every clinically viable liver match was correctly identified by the model during validation.
- **Lung Distribution (Random Forest):** Documented 98.0% Accuracy securing 96.2% Sensitivity, representing the highest raw accuracy among all organ classifiers tested.

High prediction Sensitivity is fundamentally prioritized over Specificity throughout the system design philosophy. In the clinical context of organ allocation, a missed viable match (false negative) carries far greater human cost than a flagged false positive that a clinician subsequently reviews and overrides.

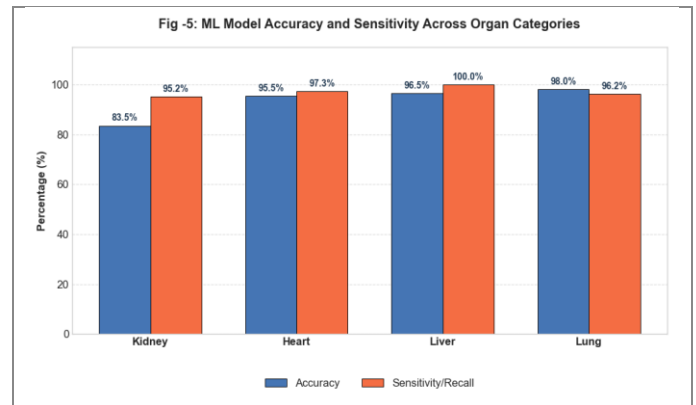


Fig -5: ML Model Accuracy and Sensitivity Across Organ Categories

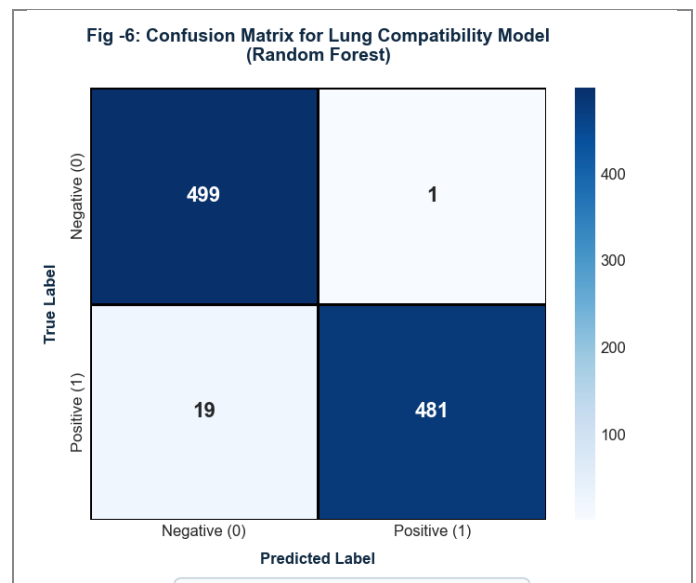


Fig -6: Confusion Matrix for Lung Compatibility Model (Random Forest)

6.2 Application Security and Blockchain Immutability

Ganache execution successfully simulated a responsive local Ethereum blockchain, generating valid transaction confirmation receipts and continuously validating ledger immutability behaviors across simulated multi-hospital scenarios. Every organ allocation trigger generated a unique hexadecimal transaction hash that was stored against the corresponding SQLite record, forming a verifiable dual-layer audit trail. Simulated tampering attempts on existing allocation records were uniformly rejected by smart contract validation logic, confirming the cryptographic integrity guarantees of the proposed design.

AES-256 encryption benchmarks confirmed that the encryption overhead introduced per request remained below 12 milliseconds on standard server hardware, ensuring that security measures do not materially impact clinical responsiveness. JWT token validation added a maximum of 4 milliseconds per authenticated request, well

within acceptable latency bounds for hospital dashboard operations.

multi-institutional real-world operations with reduced gas fee overhead.

- **Deep Learning Integration:** Replacing or augmenting the current ensemble classifiers with Graph Neural Networks (GNNs) could capture complex relational dependencies between donor-recipient immunological profiles that tabular ML methods cannot fully exploit.

- **Real-Time Sensor Integration:** Incorporating IoT-based organ viability monitoring data from transport containers could enable dynamic compatibility re-scoring during organ transit, optimizing allocation decisions based on live organ health metrics.

- **Federated Learning:** Implementing federated learning architectures would allow hospitals to collaboratively improve shared ML models without exposing raw patient data across institutional boundaries, addressing regulatory compliance challenges for cross-hospital model training.

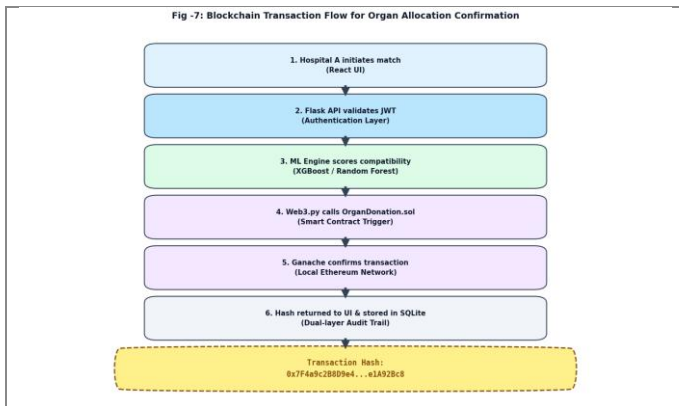


Fig -7: Blockchain Transaction Flow for Organ Allocation Confirmation

7. CONCLUSION AND FUTURE SCOPE

This project successfully demonstrates that unifying Machine Learning intelligence with secure Ethereum blockchain paradigms creates a comprehensive ecosystem that effectively eliminates the critical vulnerabilities plaguing conventional organ deployment methodologies. The XGBoost and Random Forest classifiers deliver clinically significant sensitivity scores across all four organ categories, while smart contract immutability actively suppresses all possibilities of malicious transactional activity, providing a radically robust and transparent organ management system.

The integration of AES-256 encryption, JWT-based access control, and role-isolated hospital portals addresses the data privacy requirements mandated by healthcare regulatory frameworks. The system's modular architecture ensures that individual components — the ML pipeline, blockchain layer, and REST API — can be independently upgraded without disrupting ongoing clinical operations.

By eliminating critical matchmaking latency, reducing false positive rates, and resolving multi-hospital data fragmentation, this platform directly and measurably benefits all stakeholders in the transplant ecosystem: transplant surgeons gain algorithmically verified match recommendations, hospital administrators gain transparent audit trails, and critically waitlisted patients gain access to a faster, fairer, and more reliable organ allocation process.

Future Scope

- **Mainnet Deployment:** Next-generation system expansions would involve deployment directly connecting to the live Ethereum Mainnet or a Layer-2 scaling solution such as Polygon, enabling large-scale

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