

# KIDNER – A WORLDWIDE DECENTRALISED MATCHING SYSTEM FOR KIDNEY TRANSPLANTS

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## Abstract

Individuals suffering from kidney failure today face significant challenges in order to obtain a transplant. They are placed on a waiting list and ranked by priority in hope that a kidney from a deceased donor is a transplant match. They do have another option: a living donor; someone they know, family or friend, willing to give them a kidney. These people may not be a transplant match, however there is a solution, a “Kidney Exchange” or a “Kidney Paired Donation”. In these programs, if two mismatched pairs (living donor and kidney recipient) can be grouped together so that they become transplant matches, both kidney failure patients can receive a kidney. While a great solution, these programs have a significant pitfall. They are limited to the specific registry regions participating in their program. The Kidner project was developed to help these exchange programs better detect life-saving opportunities and enable more people to access kidney transplants.

**Keywords:** transplant; kidney; privacy; security; blockchain

## Introduction

The average waiting time for a kidney transplant in the US is 3 to 5 years,<sup>1</sup> during this time patients have to go through an onerous process of dialysis at least three times a week, negatively impacting their normal

social and work life balance. Being on dialysis is expensive, about US\$60 billion is spent in the US each year on kidney healthcare - 28% of Medicare’s budget,<sup>2</sup> and transplants are overall much cheaper than ongoing dialysis. Illness may worsen while waiting for a transplant and in the worst case, patients may die.

There is another option: a living donor; someone they know, family or friend who is willing to give them a kidney. Unfortunately many factors like blood type and HLAs need to be the same and these people may not be a transplant match. To solve this “Kidney Exchange Programs” or “Kidney Paired Donation programs” (KPD), have been created.<sup>3</sup> In these programs two mismatched pairs (living donor and kidney recipient) can be grouped together so that they become appropriate transplant matches and both kidney failure patients can receive a kidney. Currently, KPD accounts for 10% of live kidney transplants in the United States. The pool of participants in KPDs face the same constraints as Traditional Cadaveric Kidney Transplant lists, they are limited to a specific country or region.<sup>4</sup> (Figure 1)

What would happen if we were to open the pool of participants in the Kidney Exchange Program to the entire world?

### Kidner Solution

Our goal is to make the current transplant system more efficient, more secure and more efficacious. To do so we realised that we need to increase the data volume by involving more hospitals in the process and asking them to share their data to create a

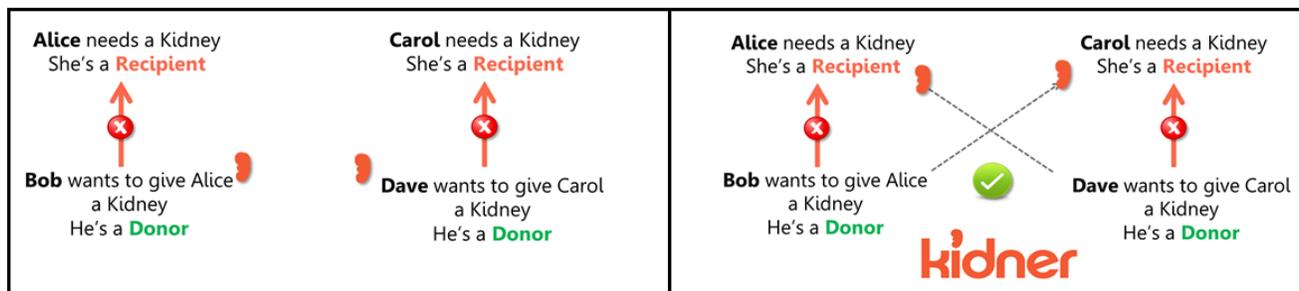
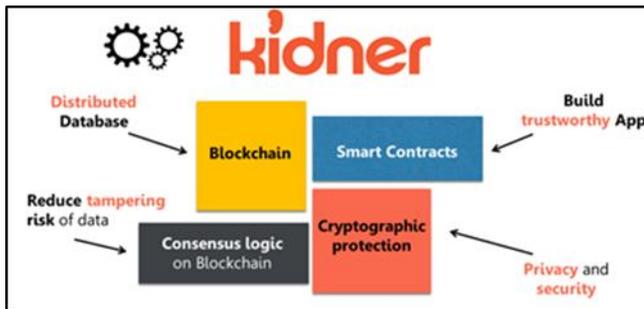


Figure 1. Kidney Paired Donation between two incompatible pairs.

bigger and more relevant pool. Such an effort requires us to address governance and trust among systems, as well as offer transparency for all actors in the system. A blockchain architecture was considered to be the best way to create a multi-parties ecosystem of hospitals and healthcare actors that want to achieve a common goal: better and safer care for the patients.

**Overview of the system architecture**

The main components of the Kidner solution are shown in Figure 2.



**Figure 2.** Main components of the Kidner solution.

**Blockchain** is a distributed ledger (database) that can only be updated by consensus among the peers that make up the blockchain network.<sup>5,6</sup> Each peer stores the ledger locally and the ledger is identical among the peers. The peers communicate in a distributed fashion to update the ledger with no need of central authority. The protocol is designed to ensure the traceability and non-repudiability of the transactions and to discourage or resist attacks or malicious behaviour on the network.

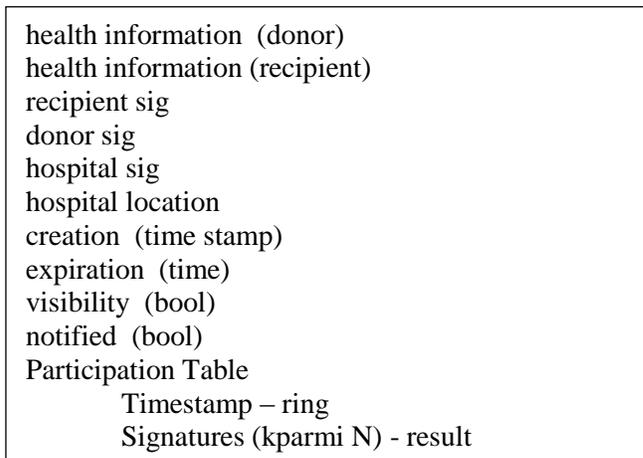
**Smart contracts** are a collection of rules which are deployed on a blockchain, and shared and validated collectively by a group of stakeholders. A smart contract can automate business processes in a trusted way by allowing all stakeholders to process and validate contractual rules as a group.<sup>6,7</sup>

**Benefits of the blockchain for this use case**

- Past transactions or blocks in the chain cannot be modified: when a piece of information is recorded it is never deleted so it is a proof that can be used and verified to prevent corruption and abuse.
- It's a powerful tool for traceability and transparency which are keys to many administrative issues in healthcare – for example the billing process. It reduces disputes between actors of the ecosystem.

- An actor cannot claim to be fully in charge of the entire process and ask every other actors of the ecosystem to trust it as a third part. Central organisation or authorities are however part of the operational solution which will give them an efficient tool for audit.

We can build a fair and transparent matching mechanism that generates non-repudiable **proof of match** because the computation is done by multiple nodes managed by various hospitals. An overview of a certificate structure is shown in Figure 3.



**Figure 3.** High-level overview of a certificate structure.

**Private, Public and (Un)Permissioned ledgers**

Requirements for blockchains vary greatly across different use-cases; there will not be a one size fits all solution.<sup>7</sup> Hyperledger opensource protocol is being designed to be highly modular, with pluggable options to suit different needs,<sup>8</sup> from open unpermissioned ledgers (e.g. Ethereum or Bitcoin) to private permissioned ledger (e.g. Bankchain).<sup>9</sup>

Compared to Ethereum or Bitcoin where the network and the ledger are open, by design, to anyone. A Hyperledger network is only accessible to authenticated members (permissioned) and the ledger can only be read and used by the members (private). It is designed for consortium or critical ecosystems, moreover some transactions can be encrypted on the ledger to preserve confidentiality.<sup>8</sup>

**Security and resiliency**

As presented in the overview, Kidner works in a distributed fashion with a high resiliency and integrity, and has no single point of failure. To ensure

that protected health information (PHI) stays protected, details surrounding the patients are anonymised by additional mechanisms before being stored in the ledger. It makes it impossible for a person to look at the medical data and identity of the patient, while making it possible for the algorithm to find matches in an automated and reliable way and notify the doctor. Only then can the doctor find the corresponding patient file on his local database.

**Proof-of-Concept**

A public opensource blockchain called Ethereum was used to illustrate the Kidner concept and the patient journey in a simple way. The front end and blockchain smart contracts described below were developed by the hackathon team of Chainhack 2015. For the proof of concept the Ethereum platform was used to implement a basic matching system through a smart contract (solidity file: <https://github.com/sajz/kidner>).<sup>6</sup>

**Kidner process**

A patient centric view of the process is described. There are two prerequisites, i) the hospital is a safe place where healthcare professionals can help the patients and provide a guarantee that there is not pressure or on going traffic into the kidney donation process, and ii) the hospital information system is secured, the database can't be breached by an attacker to steal patients data and the network is private so that no one else can listen or interfere with the internal network and critical data that are transmitted and stored.

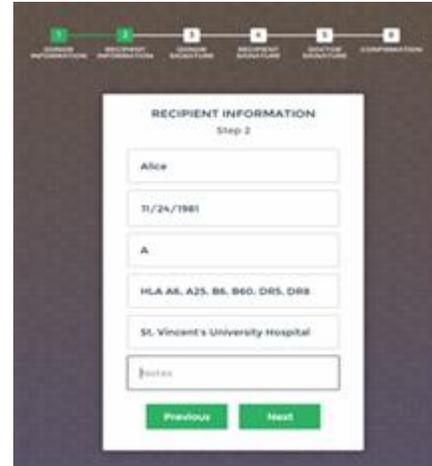
**Filling the Certificate**

Donor, patient and doctor meet at the doctor's office. They are connected through the doctor's computer on the hospital private network with direct access to the hospital database which is secured as per prerequisite (ii). Information about the donor and recipient are filled automatically from the file or by the doctor. They then individually sign a *certificate* that states 3 things:

- the donor is willing to give a kidney
- the recipient is willing to accept the kidney
- and the doctor agreed that recipient's health is good, that it is safe for him or her to have a transplant, and that the same assessment pertains the donor's health.

The doctor and the patient sign this form with a private key (multi-signature scheme), triggering the

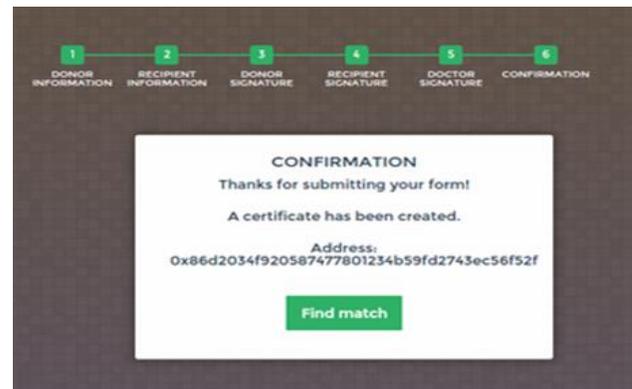
*certificate* to be anonymised, encrypted locally, and sent to the blockchain via an internet connection. (Figure 4)



**Figure 4.** Step 1 Donor information, Step 2 Recipient information, Step 3-4-5 Donor, Recipient and Doctor signatures.

**Successful update of the blockchain ledger**

At the end of the process the *certificate* is issued and can be found at its address on the Ethereum blockchain. (Figure 5)



**Last step: Disclosure**

A search is launched when Alice and Bobs doctor submits the certificate. If a match is found, the doctor will receive the hash of the address of the certificate of the Dave and Carole pair. He will then use this *proof of match* and the contact details provided by Kidner to reach out to the other Doctor. Dave and Carole's doctor will verify the *proof of match* by checking it against the local database of the hospital and confirm that it maps to an existing patient file on his side.

**Future work**

The next step is to create a consortium of actors interested in the solution described here and have pilot centres deploy the network and test it at a national scale and then between countries with similar quality and cost of care (i.e. UK and Ireland and France).

A version of the Kidner software is being developed based on Hyperledger, a blockchain protocol different to Ethereum and more suited to this use case.

**Conclusion**

Kidner is a collaborative project that was developed to address the financial and security challenges that face cross border transplantation. It aims at creating a KPD programme that extends the mismatched live donor-recipient pool through a decentralised non-profit system deployed world-wide to improve patient care and outcomes, making possible analysis and matching of patients while providing complete anonymity. It is envisaged that this system will lead to the first Kidner-based surgeries, enabling increased renal transplants per year.

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