Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 3, No. 1, 2023

Research on the Coupling of Centralized Drug Procurement based on Blockchain Technology

Pengyang Wu

Chongqing University of Posts and Telecommunications, Chongqing 400000, China

Abstract: Centralized drug procurement is an important measure to alleviate the high cost of drugs for the masses. However, due to the difficulties in platform interaction, low transparency, privacy disclosure and other problems of centralized drug procurement, the efficiency of drug circulation is low and violations emerge in an endless stream. Blockchain technology is characterized by decentralization, tamper-proof, autonomy, etc. Combined with the features of numerous participants in centralized drug procurement and large amount of data processing, a framework for centralized drug procurement based on super ledger is built, and identity registration chain code, price negotiation chain code, and contract performance chain code are designed to realize centralized drug procurement autonomy, openness, transparency, and traceability. It aims to improve centralized drug procurement and ensure transparency and accountability throughout the drug supply chain in order to maximize the effect of lower prices brought about by healthcare reform.

Keywords: Blockchain; Pharmaceutical Supply Chain; Centralized Procurement.

1. Introduction

"Seeing a doctor is expensive" is one of our most prominent social problems. In order to reduce drug prices, the state has carried out a series of medical reform measures to the pharmaceutical industry. For example, in 2018, the national medical insurance agency was established to point to "falsely high drug prices". Starting from the "4+7" national centralized bidding and procurement mode of drugs, the procurement of drugs with dosage has been carried out on a regular basis. According to statistics, the average price of the fourth batch of drugs will be reduced by 52%, which is estimated to save 12.4 billion yuan in drug costs. However, due to the characteristics of highly asymmetric information in the pharmaceutical industry, moral behavior often appears in the centralized procurement, which greatly affects the implementation effect of the centralized procurement policy. Standardizing the construction of drug procurement platform, realizing drug procurement information sharing and improving transaction transparency are urgent problems to be solved in China's centralized drug procurement at present.

Blockchain technology has the characteristics of information sharing, untampered and traceable, and is highly compatible with the problems of interaction difficulty, low transparency, privacy disclosure and other issues of the centralized drug procurement platform. It can regulate the behavior of centralized drug procurement and effectively solve the moral misconduct of review experts. Therefore, this paper builds a centralized drug procurement system based on the super ledger platform, establishes chain codes of qualification review, double-envelope system and other rules, combines with automatic review and expert review of blockchain chain codes, which can not only realize a traceable and transparent bidding mode, but also further improve the centralized drug procurement system, achieve drug cost reduction and efficiency, and effectively guarantee the public use of drugs. We will improve the accessibility and affordability of medical services.

1.1. Study on Centralized Drug Procurement

Centralized purchasing of drugs has promoted the formation of competition based on quality and cost in Chinese pharmaceutical market, and greatly promoted the increase of concentration in pharmaceutical industry. Some experts even point out that centralized drug procurement is the only way to deepen China's medical reform (Chen Zhihong et al., 2021) [1]. At present, scholars have conducted a large number of studies on centralized drug procurement, which can be summarized as follows:

(1) Study on centralized purchasing mode of drugs at macro level. Implement centralized online bidding and procurement of drugs for medical institutions in Guangzhou, and improve the government's drug pricing mechanism (Chen Bo, 2007) [2]. By comparing the advantages and disadvantages of typical national drug bidding and procurement, it concluded that the reform of centralized drug bidding is in the right direction and should be adhered to by discarding some wrong ideas (Sun Xue et al., 2011) [3]. Based on the centralized drug procurement model and process of the UK, suggestions were put forward in terms of medicine separation, drug price formation mechanism, adjustment of medical insurance reimbursement list, and promotion of rational drug use (Li Qian et al., 2016) [4]. The establishment of medical insurance in 2015 marked the deepening of medical reform. "4+7" drug procurement with specific volume is the breakthrough in the new medical reform period. National Healthcare Security Administration is the representative of the pilot organization to carry out specific volume procurement, aiming at exploring "two mechanisms" and realizing "four effects" (Yu Changyong, 2020) [5].

(2) Study on drug collection policy at mesoscopic level. Since the implementation of the centralized bidding policy, many local bid-winning enterprises still need to conduct "second price negotiation" with medical institutions on the basis of the purchase price determined by the government. By analyzing the motivation, conditions and implied real demands, the defects of the current mechanism were pointed out and the improvement of the drug price mechanism was

proposed (Wang Zhenping et al., 2014) [6]. With the implementation of the new medical reform, in order to reduce circulation links, the country encouraged the implementation of "one-vote system" in 2015, analyzed the advantages and disadvantages of the distribution mode from four aspects of logistics, information flow, capital flow and quality management, and suggested the coexistence of "one-vote system", "two-vote system" and "multi-vote system" to gradually transition to the "one-vote system" distribution mode (Ding Jinxi, Tian Ran et al., 2016) [7]. At the end of 2016, The State Council announced the implementation of the two-vote system. The centralized drug purchasing mechanism mainly uses bidding groups to distinguish drug quality levels, achieving the basic principle of "quality first" in purchasing. Statistical analysis was made on the latest documents concerning bidding groups in various provinces to find the main problems existing in bidding groups, and explore and improve bidding groups based on this (Ding Jinxi, Dong Rui et al., 2016) [8]. The "4+7" procurement of drugs is to adhere to the innovation of the medical insurance system with Chinese characteristics centering on people's health, and is an important institutional arrangement for further deepening the reform of the medical and health system (Zhou Qian, 2020)[9].

(3) The perspective of drug procurement at the micro level. In order to improve our drug bidding procurement system, we refer to the drug bidding procurement system of European Union countries, and discuss the relationship between the drug cost and the drug bidding procurement subject under the corresponding mechanism based on the drug cost payment method (Zhao Bin et al., 2012) [10]. Analyzed the development status and operation mode of GPO in the United States, analyzed the function of GPO, and finally put forward some suggestions on the centralized procurement of medicine in our country (Wang Fan et al., 2016) [11]. From the perspective of corporate moral failure, the reasons for the low performance of centralized drug procurement and feasible improvement measures were explored (Wu Hanhong et al., 2017) [12]. This paper explores the reform promoted by the establishment of the medical insurance Bureau for the supply and demand side and the supply side, and analyzes the three challenges it faces: the public budget system of medical insurance, the standardization and institutionalization of the reform of medical insurance payment, and the reform of the medical price system (Gu Xin, 2019) [13]. Moreover, the empirical analysis of the "4+7 belt procurement" implemented in three rounds is carried out to interpret the influence of the three procurement rules on the practical effect, and it is found that the selection rules have a significant impact on bidding (Chen Zhihong et al., 2021) [14].

1.2. Blockchain Technology Coupling Research

Blockchain technology, as a new technology that may trigger disruptive industrial innovation, has triggered a scramble for research and application in the academic field (He Xiaodong et al., 2018)[15]. It is mainly applied in energy, finance, supply chain and other related fields, but there are few researches on the coupling of blockchain in the pharmaceutical supply chain, which mainly focus on the patient electronic medical record: 1) on the privacy and sharing of electronic medical record data. In order to solve the privacy and data integrity problems of patients' electronic medical records, a blockchain scheme for sharing electronic medical records based on red-black tree was proposed (Zhou Yihua et al., 2021)[16]. In view of the difficulties of data interaction in medical institutions and the easy disclosure of user privacy, a blockchain based HER sharing scheme was proposed (Luo Wenjun et al., 2020) [17]. 2) On safe storage of electronic medical record data. The traditional electronic data mode of Chinese medical treatment leads to the problems of slow circulation and security of medical data storage, so a data storage mode based on blockchain is proposed (Wang Hui et al., 2019) [18]. In addition, it is also used in the fields of drug tracing and pharmaceutical resource scheduling. For example, in the context of the serious threat of counterfeit drugs to the pharmaceutical industry, a blockchain-based TCM supply traceability model was built (Xiao Yong, 2021) [19], and a drug traceability system was built using the super ledger fabric platform from a systematic perspective. Its operability and practical significance further realized the full traceability of drugs (Mueen, 2021) [20]. Build a public service platform for distributed scheduling of medical business resources based on blockchain (Bi Ya, 2018) [21]; Ethereum platform was applied to build automated procurement chain code of pharmaceutical and healthcare supply chain, and solve the problem of time-consuming and inefficient procurement of group purchasing organization (GPO) (Omar,2021) [22].

To sum up, centralized drug procurement is the only way to deepen the reform of Chinese medicine. Most scholars mainly focus on mode exploration and the influence of policy on members, few scholars study and build the centralized procurement system. Centralized drug procurement based on blockchain technology, which is tamper-free, anonymous, autonomous and other characteristics highly meet the information of extreme asymmetry. This paper proposes to build an open, transparent, fair and just centralized procurement system based on the framework of super ledger.

2. Current Situation of Centralized Drug Procurement

2.1. Centralized Drug Procurement Model

Since 1993, Henan Province began to explore the centralized drug procurement mechanism. Under the environment of continuous development and reform, such as local exploration, national pilot and national promotion, the State organized the establishment of the National Security Bureau to solve the fundamental problems of the absence of medical insurance institutions and the profit-seeking of public medical institutions for a long time, and implemented the "integration of recruitment and procurement, linking quantity and price". The pilot promotion of "4+7 procurement with quantity", and the determination of the criteria for finalists and the implementation of double-envelope bid evaluation measures, avoid the phenomenon of "bad money driving out good money" in the drug market, not only reduce the price of "expensive drugs", but also further promote the integration of the Chinese drug industry. The operation process of "4+7 procurement with quantity" is shown in the figure: (1) Public medical institutions report drug demand; (2) Collective procurement and integration of demand, public bidding; (3) Pharmaceutical enterprises make plans and participate in bidding; (4) Bid evaluation shall be conducted, the shortlist shall be determined, and both parties shall negotiate and sign a contract; (5) The results of collecting and working; (6) The parties shall conduct fund settlement and logistics distribution for the performance of the contract.

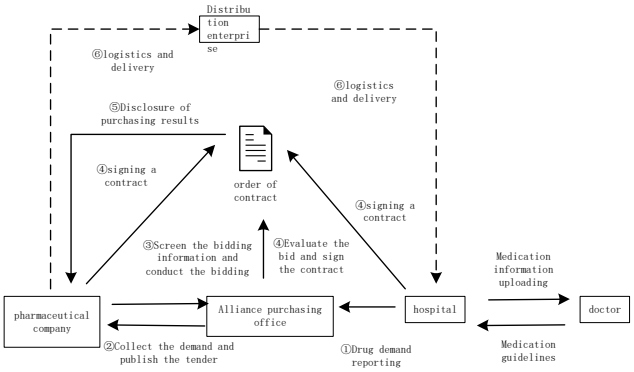


Fig 1. Centralized drug procurement process

2.2. Existing Problems of Centralized Drug Procurement

Centralized procurement of drugs has become the main procurement mode of public medical institutions, which is an important act to alleviate the high cost of drug use among people. But at present, the concentrated procurement also faces some problems, such as difficult information sharing, opaque bidding transaction, and privacy disclosure of the bidding subject. It is mainly reflected in:

1. The membership relationship of the platform is complicated and the interaction between members is difficult

Since the reform of drug decentralized procurement to centralized procurement, the mode of drug centralized procurement has presented diversified development, mainly provincial centralized procurement and national centralized procurement, such as: Guangdong Drug Trading Center (national procurement platform), Chongqing Drug Exchange (provincial procurement platform), etc. The complicated affiliation relationship between platforms and different management modes results in the fragmentation between platforms, leading to the island phenomenon of difficult information interaction and sharing. In order to obtain demand information, pharmaceutical companies often spend a lot of time on information screening between major platforms and prepare qualification review materials according to different requirements of the platforms, which seriously hinders suppliers from joining the centralized drug procurement market. It not only increases the intermediate cost of bidding and purchasing, but also greatly reduces the operation efficiency of centralized procurement.

2. Lack of openness and transparency in trading and market fairness

Open and transparent transaction is an important mechanism to maintain market fairness, and also the information source to support the decision-making of pharmaceutical companies. However, it is currently in the national promotion period of "4+7 procurement with quantity", and the implementation of relevant policies is different in different provinces. The announcement of information such as tender publicity, bidding list, expert evaluation and winning result is not timely or deliberately delayed, or even directly internal evaluation and cancellation of the publicity of relevant information. Among them, in the bidding process, there are some unethical behaviors such as bidding by pharmaceutical companies, unfair experts, and local protectionism in some provinces, which seriously violates the basic principles of fairness, justice and openness, making it difficult for pharmaceutical companies to match the actual market demand, and the public drug prices remain high.

3. Poor implementation of the system and vague supervision of power and responsibility

The pharmaceutical industry has always been a highly specialized and concentrated industry, and there are restrictions in the professional field in every link of the transaction, and this high information asymmetry is the main reason for the inflated price of drugs. In the process of centralized drug procurement, due to the huge difference between raw materials and manufacturing process of drugs, as well as the wide variety of drugs, the government is unable to grasp the precise cost and quality of drugs. Pharmaceutical companies take the opportunity to lie about cost and quality for personal gain, which promotes the market failure of "bad money drives out good money". "4+7 procurement with quantity" adopts the double-envelope system, in which the economic index sets the threshold for bidding to ensure the quality is the priority, but the system is useless and difficult to be implemented because the experts are not expert in evaluating bids, collecting bribes and pursuing accountability.

4. The bidding process is "centralized" and the behavior is rampant

The bidding process is an important part of centralized drug procurement, and the privacy protection of the subject of bidding is the key to maintain a fair and just environment for bidding. The order volume of centralized drug procurement accounts for a proportion of the drug market, so order grabbing is very important for the market share of pharmaceutical companies, which will not only stabilize the reputation of pharmaceutical companies in the market, but also bring important protection for the capital expenditure of pharmaceutical companies in production and research and development. In order to obtain bidding orders, pharmaceutical companies spent a lot of money to bribe government bidding staff to disclose key information such as bid evaluation criteria, bidding conditions of pharmaceutical companies and relevant economic and technical indicators, disrupting the order of the platform. The disclosure of bidding information will bring information advantages to competitors, which is conducive to the integration of its own resources to revise the bid according to the situation of other pharmaceutical companies, or to negotiate with other bidders to ensure that pharmaceutical companies win the bid and other illegal operations, and to conduct bidding, bidding, bid control and other illegal behaviors. Summary and suggestion

3. Construction of Centralized Drug Procurement Model based on Blockchain Technology

3.1. System Architecture

Based on the framework of the super ledger platform, this paper links the recruitment bodies of the pharmaceutical industry and relevant government departments to build a centralized drug procurement system with autonomy, open and transparent information to provide systematic support for the centralized procurement of the new medical reform. As shown in the figure, it consists of four parts: block chain layer, chain code layer, network layer and application layer. In the blockchain layer, data transfer is realized through application programming interface (API), transforming traditional core enterprise data management into distributed multi-center data management. The chain code layer is the chain code that needs to be called when the alliance chain nodes interact with each other, and realizes the autonomy of business processing

by triggering the preset response condition. The main function of the network layer is to provide a stable, secure and reliable p2p network channel to ensure the information exchange between nodes. The application layer is the bridge between the participants and the super ledger, which solves the software development kit (SDK) to quickly build the functions required by users. The collecting subject selects the function instruction input with the help of the decentralized application (DApp), triggers the chain code to generate the event after the information interaction between the nodes of the network layer, returns the response result and displays the instruction result at the application layer. At the same time, it is compiled and deployed in the blockchain layer to produce immutable blocks.

Drawing on the "4+7 purchasing mode" led by medical insurance institutions, the system integrates the drug demand of public medical institutions, supports bidding and purchasing business, creates a fair, open and just trading environment, and provides functional services such as user identity registration, member management and drug management. The system selects the super ledger fabric platform, which has a complete distributed network framework, pluggable consensus mechanism, distributed file storage solutions and other solutions. It provides a safe and reliable network environment for the interaction between collection subjects, so that participants can reach a consensus to carry out transactions in the designated channel, and ensures the decentralized distributed storage of transaction data. Can ensure the integrity and privacy of its transaction execution. In this platform, before the participants enter the system, they need to upload the information and have the identity certificate issued by the identity agency; After identity authentication, the peer node exists in the network of super ledger as the identity of peer node, which is a single node in the distributed network of super ledger, used to update and query the general ledger, and is divided into endorsement node, submission node and sorting node. The interaction process is roughly as follows: the node submits the transaction application after authentication and negotiation by the endorsement node. Then, the sorting node carries out packaging sorting to generate blocks with time stamp and other identification code characteristics, and its network communication mechanism will broadcast the information to the main node in the chain, and then pass it to the verification node for review, to ensure that the transaction is executed in accordance with the endorsement strategy signature endorsement, and finally generate new blocks on the blockchain and update the ledger.

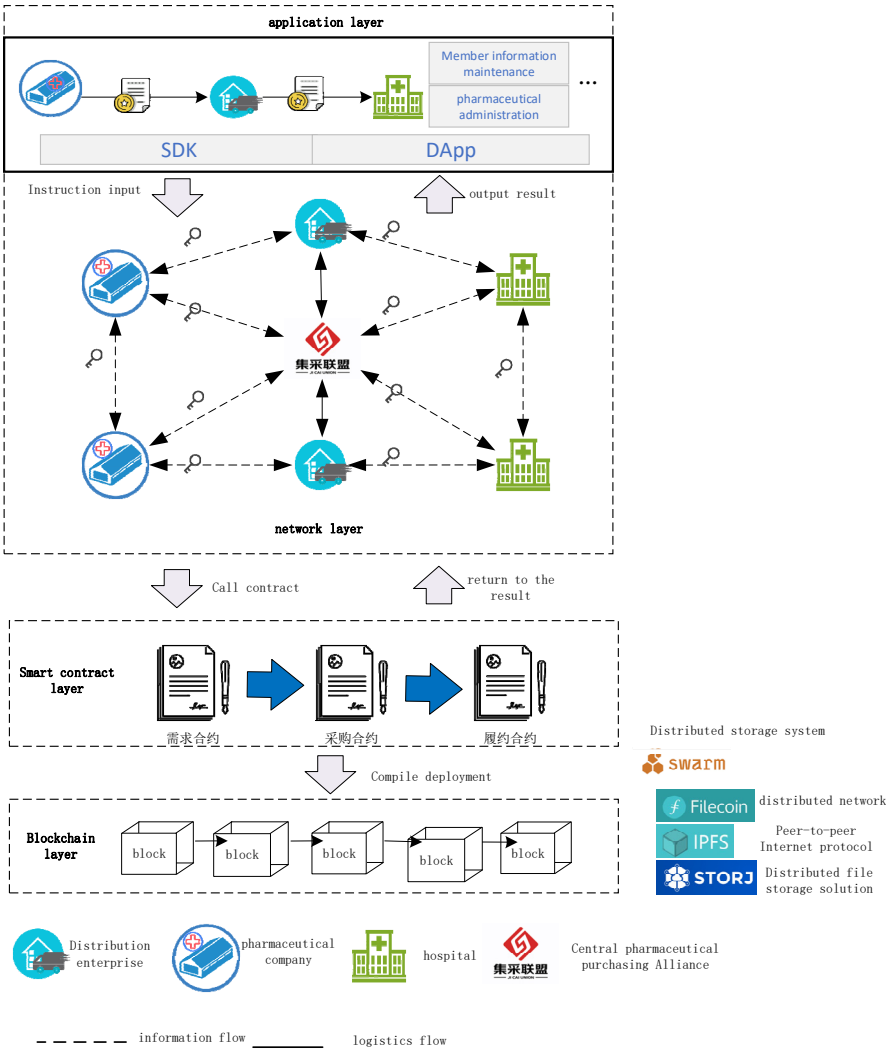


Fig 2. Block diagram of centralized drug procurement system based on blockchain

3.2. Chain Code is Applied to Business Integration Logic Processing Specification

Chain code is a very important part of the super ledger, it is currently used to implement the most common programmable computing protocol in blockchain technology, also known as chain code. Chain code is created and executed by peer nodes to store and change the status information between

participants in the interstellar file system. Developers use chain code to interact with super ledger for business development, asset management and business operation. Its operation logic presets the trigger scenario of the chain code for if-then and what-if statements. When the condition is triggered, the chain code executes the corresponding service, and finally submits the generated result to the channel specified by the fabric for linking.

In order to realize the transparency and fairness of the centralized drug procurement platform, identity registration chain code, price negotiation chain code and contract fulfillment chain code were proposed. These chain codes are used for the identity registration of participants in the joining chain. After the pharmaceutical enterprise passes the double-envelope bid evaluation, the pharmaceutical enterprise negotiates and signs contracts with the collection and Purchase Office, and the supplier and public medical institution perform the contracts on capital settlement and logistics distribution.

Identity registration chain code. The collection participants will initiate and deploy the registration chain code, which is used to register basic information on the platform. The participant creates and executes register () function to register the company. The chain code qualification includes the company's operation qualification certificate and drug license, etc. After being verified by the certificate authority, the identity registration chain code sends the identity certificate to the participant. When the participant carries out centralized drug purchase, the participant uses the CA certificate to enter the platform. In the process of price negotiation chain code, the identifier with CA certificate is used for identification and function authority setting in drug negotiation and contract performance.

Price negotiation chain code. A price negotiation chain code will be automatically deployed once a supplier has launched a price bid following the publication of a public bid. The supplier creates and executes the addContract () function for bidding. Within the specified time, the tender is divided into purchase groups through drug consistency evaluation. After the supplier passes the qualification examination, the drug price negotiation is carried out. Until both parties reach an agreement, complete the price negotiation chain code, then generate the contract, and execute the contract performance chain code. At the same time, after the completion of a round of centralized drug procurement, the platform publicized the collection information.

Contract performance chain code. After completing the price negotiation chain code, the contract performance chain code will be followed by capital settlement and logistics distribution. The public medical institution shall first pay the deposit of the supplier contract. After the completion of the logistics and distribution contract, the balance settlement of the drug contract shall be completed according to the provisions of the contract. During the performance of the contract, the breach of contract will be publicized on the platform. When the supplier executes logistics distribution, it can update the transaction of the drug container by calling updateTr () function. The transaction information includes batch drug information, status, etc., such as goods ID, quantity, storage temperature, etc., and traceability of information can be realized by executing the chain.

3.3. Implementation Mechanism of Block Chain in Centralized Drug Procurement

This section describes an implementation of centralized procurement based on the fabric framework that enables the platform to use fabric to perform order validation architecture processing and execute transactions between participating actors on a blockchain network. Transaction processing between participants is completed through the autonomy of chain code, and all transaction-related activities cannot be tampered with by blockchain, so as to achieve transaction fairness and platform transparency.

First, drug collection institutions identify, register and register participants in a p2p super ledger structure blockchain network. The registration function will be performed in the chain code, with the collecting agency acting as the certificate authority. It creates a private collection network that is only available to registered stakeholders. All participants will connect to the registration system via a virtual private network to run an additional layer of security. At the time of registration, the supplier calls register () function to submit the basic information such as the company name, address, contact information, operation qualification and so on to the certificate authority. The certificate authority checks the supplier's operation qualification and sends the identification certificate and stores the information on the chain. Other participants also complete identity registration through this step and wait for the execution of the contract.

After the platform announces the bidding information, the registered suppliers enter the platform through the CA certificate and bid on the bidding documents according to the company's requirements. The bidding documents include drug specifications, dosage, type and other information, and the bidding documents are directly sealed and linked to the blockchain. Within the specified time, the suppliers complete the bidding stage according to the requirements, and the evaluation experts conduct the evaluation in the designated work area. Review experts log in the authorized account to call the bid view function, decrypt the bid call chain code for autonomous qualification review, review experts conduct consistency assessment on the bid according to the review standards, complete bidding grouping according to generic drugs and original research drugs, and score review experts on the chain to store transaction data. Based on the basic principle of volume pricing, both parties offer prices in the price negotiation function. Through negotiation () function, both parties reach an agreement on the price and then generate a contract with information about the type, quantity, price and distribution company of the drug. After the conclusion of the public bidding negotiation, the transaction information will be publicized on the platform network.

Upon completion of the negotiation transaction, a contract fulfillment chain code is executed between the public healthcare provider and the provider, which is updated by calling the updateTr() function to contract for transport-related information, which is updated to all stakeholders. Create and execute the updateTr() function to track drug-related information at source, drug registry management chain code based on manufacturer activity, consignment, drug-related information, drug registry information (including time stamps), drug metadata, and geographic information.

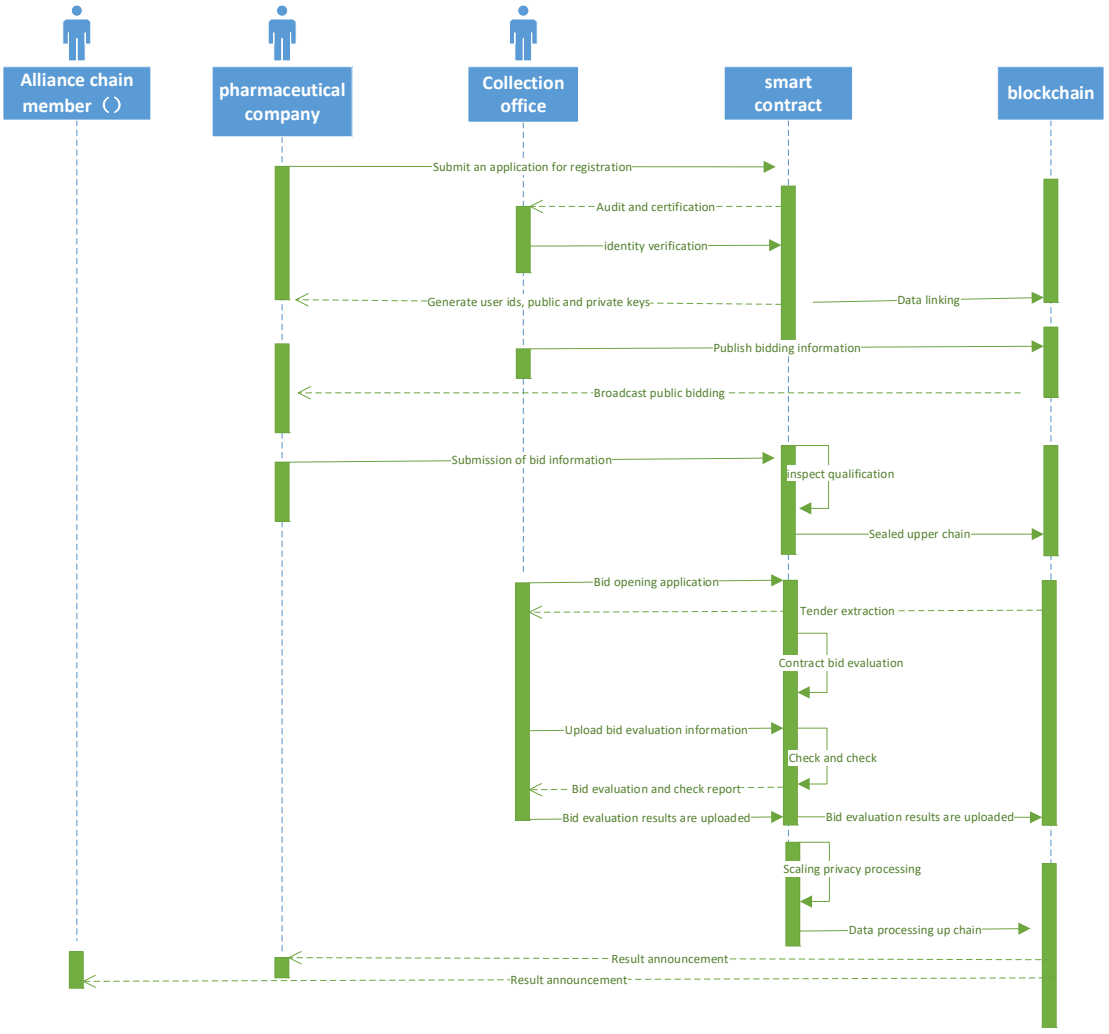


Fig 3. Interactive process of centralized drug procurement

4. Conclusion

This paper analyzes the current situation of the centralized procurement of medicine, summarizes the main problems of the centralized procurement mode, and builds the centralized procurement system of medicine based on the super ledger. The system uses alliance chain as the main chain, improves the data processing ability and information traceability efficiency, realizes the open and transparent fair mechanism of drug collection, guarantees the traceable mechanism of drug purchase, and restricts the unethical behavior of recruiting and purchasing members. The introduction of blockchain technology is an inevitable trend in the development of centralized purchasing platforms of medicine and an inevitable requirement to promote sustainable and healthy development of the pharmaceutical industry. However, at present, there are still technical barriers to blockchain technology, coupled with the lack of relevant infrastructure conditions. The state should support the introduction of blockchain technology on the platform in terms of policies and increase investment in platform upgrading.

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