A Smart Chest Pain Center to Improve Quality Control and Reduce Doctor’s Workload of Acute Myocardial Infarction

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Abstract: The establishment of a chest pain center (CPC) is an important strategy to improve the treatment of urgent cardiovascular disease, especially acute myocardial infarction. In order to monitor and continuously improve the quality of diagnosis and treatment of CPCs, accurate records of key time points must be made in the diagnosis and treatment of fatal chest pain, which consumes tremendous manpower and resources. Our research combined the application of the Internet of Things, big data, artificial intelligence, and other techniques, to establish a smart CPC that can automatically record key time points, which significantly reduced the workload of doctors with more reliable, unified, and traceable data. Our solution to the CPC should be a promising plan for future CPC construction.

Key Words: automatic recording, big data, chest pain center, key time points

Acute myocardial infarction (AMI) is a worldwide public health problem with high incidence and mortality. The estimated number of AMI patients admitted to hospital in China could be more than 200,000 in 2011 and is still rapidly increasing. It is noted that the mortality of AMI is unacceptably elevated in China, even though the number of patients underwent primary percutaneous coronary intervention (PCI) was also increasing. The reason for the elevation of the mortality in China could be various. First, the patient and systemic delay is still much longer than the guideline’s requirement in China. Second, the reperfusion rate of AMI patients is still less than 50% in China. Third, the patient may not receive the optimal medication therapy during and after hospitalization. It is indicated that the quality control of the whole AMI treatment process needed to be improved from the 3 factors.

The establishment of chest pain center (CPC) is the best way to facilitate the quality of the whole AMI treatment process at present.

In order to ensure that all the patients in different CPC can receive optimal treatment, the American College of Cardiology (ACC) and the headquarter of China CPC design similar quality control rules and guideline. It stipulated the longest duration of each step from patient entering CPC to the reperfusion. It is quite reasonable to design the rule because the prognosis of AMI is apparently time dependent. Moreover, the duration data are also of great importance for quality improvement. However, recording all the data accurately is a difficult task for doctors since the doctors cannot record the data and treat the patient simultaneously. Moreover, recording the data afterwards often brings mistakes. Therefore, some new solution is needed, which can record the data automatically and accurately. With the development of 4G (even 5G) network and artificial intelligence technology, our team established an automatic CPC recording system, which we call it a smart CPC.

WHAT IS THE FUNCTION OF THE SYSTEM?

The principal purpose of the system is to record the whole in-hospital treating process of a chest pain patient. Since AMI is such a severe and time-dependent disease, our system has the following specific function: (1) real-time tracking of patient location information; (2) automatically recording all key time points as listed in Table 1, which are all crucial for the quality control of the AMI patient treatment in CPC. (3) Automatically uploading pivotal auxiliary examination results such as electrocardiography (ECG) and cardiac biomarkers (troponin, myoglobin, creatine kinase-MB, and brain natriuretic peptide) and treatment prescribed to patients. (4) All the patient’s information must be confidential and only visible to authorized person. After the application of the smart CPC system, every authorized staff can get detailed information about the patient such as the position, the treatment, and the key point time, no matter when and where the staff is.

WHAT DOES THE SYSTEM INCLUDE?

To meet the above demands, our system integrated various hardware and software as follows:

Hardware: smart robot (Shanghai Fucong Financial Information Service Co., Ltd.), smart band (Shanghai Fucong Financial Information Service Co., Ltd.), smart terminal, Bluetooth low energy (BLE) base station, edge computing server (Shanghai Fucong Financial Information Service Co., Ltd.), 4G/WIFI router, WIFI bridge, integrated electrocardiograph (SID Medical Technology Co., Ltd.), integrated cardiac biomarker detector (Shanghai Xingtong Co., Ltd.), etc. The function of the hardware was all listed in Table 2.

Software: special application (Xinxia) and small Wechat program (Xinxia) for CPC. The software shows all the patient’s information such as position, treatment, and test results to the authorized staff.

HOW DOES THE SYSTEM WORK?

The system covers the entire process of patients in the triage, CPC, cardiac care unit (CCU), and catheter laboratory (Figs. 1 and 2).

Triage
After a patient with chest pain enters the emergency department, the nurse at the triage desk guides or assists the patient to get...
| Critical Time Point | Definition of China CPC Headquarters | Definition of the Smart CPC System |
|---------------------|--------------------------------------|-----------------------------------|
| 1 Time of arrival at hospital gate | The time when patient enters the gate of the hospital, if tracking the time is difficult, the time point can be replaced with registration time or time of arrival at triage desk according to hospital’s practical condition | Recognition as the time the patient arrived at the emergency department or 1 minute before the time of clinical reception |
| 2 Time of clinical reception | The time of the first contact between the medical staff and the patient | The time when patient arrives at triage station, start emergency process |
| 3 Time of first medical contact | The time of first contact with doctor after the symptom onset. | The time when patient arrives the CPC consulting room (should be modified manually if the patient is transferred by ambulance). |
| 4 Time of the first ECG in hospital | The completion time of the first ECG after admission (including outpatient department and emergency department) | Identifying the completion time recorded by the integrated ECG device |
| 5 ECG diagnosis time | The time of the first ECG interpretation by the specialist | 2 minutes after the completion of the first ECG test in the hospital |
| 6 The time of the blood sampling | The time when the patient receives the first blood sampling of cardiac biomarker | Recognizing the start time of the testing by the integrated cardiac biomarker detector |
| 7 Time of the cardiac biomarker report | The time when the doctor receiving the first cardiac biomarker report | The report time recorded by the integrated cardiac biomarker detector |
| 8 Time of first administration of antiplatelet drug | The time when patient take the antiplatelet drugs | Recognizing the time when the doctor prescript antplatelet drugs to the patients (AI voice recognition technique) |
| 9 Time of the arrival at CCU | The time when patient arrives at CCU (if the patient does not receive primary PCI immediately) | The recognition time of patients entering CCU by BLE base station |
| 10 Time of the decision of interventional procedure | Time when the specialist decides to perform interventional procedure | The recognition time when the specialist informs the patient to receive an interventional procedure (AI voice recognition technique) |
| 11 Time of starting the catheter laboratory | The time when the specialist informs interventional cardiologist to start catheter laboratory | Identifying the time when the specialist informs interventional cardiologist to start catheter laboratory (AI voice recognition technique) |
| 12 Time of starting the informed consent | The time when the specialist starts to inform the patient and the relatives about the procedure. | Recognition of the time when the specialist start the preoperative informed consent conversation (AI voice recognition technique) |
| 13 Time of signing of the informed consent | The time when the relatives of the patient signs the informed consent | Recognition of the time when the specialist uploads the informed consent |
| 14 Time of the activation of the catheter laboratory | The time when the catheter laboratory is ready to receive the patient | The time when the interventional cardiologist informs the CPC specialist or CCU cardiologist to transfer the patient (AI voice recognition technique). |
| 15 Time of the patient arrival at catheter laboratory | The time when the patient arrives at the catheter laboratory | Recognition of the time when patient is transferred to catheter laboratory by BLE base station |
| 16 Time when the puncture starts | The time when the doctor or his assistant starts to puncture the radial artery or femoral artery | The time when the device recognizes the characteristic motion of the puncture (usually the motion of picking up the puncture needle) |
| 17 Time of puncture success | The time when the doctor or his assistant successfully punctured the radial artery or femoral artery | The time when the device recognizes the characteristic motion of the doctor or his assistant finishing puncturing (usually the motion of withdrawal of the sheath inner core) |
| 18 Angiography starting time | The time when the angiographic catheter is inserted into the sheath | The time when the device recognizes the characteristic motion of the insertion of the angiographic catheter (usually the motion of the insertion of the catheter into the sheath) |
| 19 Angiography ending time | The time of the completion of coronary angiography | The time when the device recognizes the characteristic motion of angiography completion (usually the catheter withdrawal after left and right coronary angiography) |
| 20 Time of the first balloon dilation | The time of the first balloon dilation | The time when the device recognizes the characteristic image of the balloon dilation |
| 21 Procedure ending time | The ending time of coronary intervention | The time of the last angiographic image obtained |

AI indicates artificial intelligence; BLE, bluetooth low energy; CCU, cardiac care unit; CPC, chest pain center; ECG, electrocardiography; PCI, percutaneous coronary intervention.
and wear the smart wristband by using the smart robot, then the smart wristband starts to record the time.

**CPC Consulting Room**

The BLE base station in the consulting room will detect the patient and record the time through the smart wristband once he/she enters the room. The bedside integrated ECG will be used to finish the first electrocardiogram and record the time. Then the doctor will analyze the report, and ECG machine will automatically upload patient's ECG report, time of the first ECG in hospital, ECG diagnosis time to the terminal. The blood sampling time of the cardiac biomarker test is recorded by the bedside integrated cardiac biomarker detector. The report time of the blood test is recorded as the time when the detector finishes the report.

If the doctor determines that the patient needs to receive pPCI, the doctor will start preoperative informed consent conversation with the patient or the relatives. After the patient signs the informed consent, the cardiologist will start preoperative informed consent conversation with the patient or the relative. Smart wristband will identify the time point when starting the conversation to sign the informed consent. After the patient signed the informed consent, the cardiologist uploaded the informed consent. The time point was recorded as the time of signing the informed consent. Subsequently, the wristband can identify the time when the CCU physician informs interventional cardiologist to start catheter laboratory as time of starting the catheter laboratory.

**WHAT IS THE ADVANTAGE OF THE SYSTEM?**

The smart CPC system has been applied smoothly in Shanghai 10th people’s hospital for 12 months. The system was applied to 1171 patients suffering from chest pain. During the application period, the probability of data error of the system is only 1.5% (369/24,591), which is very low. The data error was defined as the ratio of the number of data that was abnormal or missed out and need manual modification and the number of total data input. Of note, these data were all automatically obtained synchronously during the patient visiting to CPC, which should be much more accurate than manually recording it afterwards. We concluded several advantages of the system over standard CPC. First of all, the smart CPC system can reduce the data heterogeneity caused by different medical information systems and logic algorithms used in different hospitals. Second, compared with traditional CPCs who manually recorded key time points by medical staff afterward, the smart CPC system can record key time points automatically, real-time, accurately, and comprehensively. On the one hand, it can reduce the inaccuracy of data caused by traditional methods. On the other hand, it can greatly reduce the workload of medical staffs. Third, the reliability and consistency of data can further provide valuable data for the health policy formulation.

**A REPRESENTATIVE CASE OF THE APPLICATION OF THE SYSTEM**

A 59-year-old male with chest pain came to the hospital on November 1, 2020 (Fig. 3). With the help of the nurse and the smart robot, patients received and activated a smart wristband at 12:57 in the triage; the system automatically recorded the time of arrival at hospital gate 1 minute before the wristband activation. Then under the guidance of smart robot, he arrived at the CPC consulting room; the BLE base station sensed the patient’s position and recorded the time of the first medical contact (12:58). Subsequently, the specialist performed a bedside ECG by the integrated ECG machine, and the time of the first ECG in hospital was recorded at 12:59. Then, the ECG diagnosis time (13:01) was recorded 2 minutes after the completion of the ECG test. Meanwhile, the ECG image and report were uploaded to the system.

for further treatment. When the patient is transferred to CCU, the BLE base station at the gate of CCU will sense the signal from the smart wristband and record the time of arrival at CCU; after arrived in CCU, if the patient still needs to receive pPCI according to patient condition assessed by CCU cardiologist, the cardiologist will conduct preoperative informed consent conversation with the patient or the relative. Smart wristband will identify the time point when starting a conversation to sign the informed consent. After the patient signed the informed consent, the cardiologist uploaded the informed consent. The time point was recorded as the time of signing the informed consent. Subsequently, the wristband can identify the time when the CCU physician informs interventional cardiologist to start catheter laboratory as time of starting the catheter laboratory.

**Catheter Laboratory**

The patient was then transferred to the catheter laboratory for pPCI. After entering the catheter laboratory, the BLE base station at the gate of catheter laboratory will sense the signal from the smart wristband and record the time of arrival at catheter laboratory; during the procedure, an artificial intelligence-based motion and image analysis system can identify the characteristic motion or image from the camera or computer and recording the key time points including the time of starting the puncture, time of finishing the puncture, time of starting coronary angiography, time of finishing coronary angiography, and time of the first balloon dilation and time of the end of procedure (Table 2, number 16–21). After the procedure, the patient will be transferred to CCU for further treatment.

**TABLE 2.** The Main Hardware of the Smart CPC System and Its Function

| Hardware                | Function                                                                 |
|-------------------------|--------------------------------------------------------------------------|
| 1 Smart robot           | Register the patient information, help the patient to activate the smart wristband |
| 2 Smart wristband       | 1. To record the location of the patient.                                 |
|                         | 2. To record the sound around the patient and connected with intelligent voice analysis system to recognize some specific time point |
| 3 Smart terminal        | Receiving the real-time key time points and diagnosis and treatment data of the patient at emergency treatment process and tracking the patient’s emergency treatment process. |
| 4 BLE base station      | The BLE base station was equipped in each diagnosis and treatment area to track the patient’s emergency process and position. |
| 5 Edge computing server | Accelerating the process and transmission speed of patient diagnosis and treatment data to reduce the delay. |
| 6 4G/WIFI router        | Provide network support                                                  |
| 7 WIFI bridge           | Provide a local area network connection                                  |
| 8 Integrated electrocardiography | The ECG device can automatically upload the patient’s electrocardiogram report, the first electrocardiogram time, and the electrocardiogram diagnosis time to the system. |
| 9 Integrated cardiac biomarker detector | Automatically sending the patient’s cardiac biomarker (troponin, creatine kinase-MB, and myoglobin) report, blood sampling time, and report time to the system after the test. |

BLE indicates bluetooth low energy; CPC, chest pain center; ECG, electrocardiography.

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The ECG of the patient was initially diagnosed as acute ST-segment elevation myocardial infarction, and then be transported to CCU for further treatment. When patient arrived CCU doors, BLE base station positioned to the intelligent wristband, recorded the time of the arrival at CCU (13:17), then the CCU doctor told to the patient and families that patient should be conducted percutaneous transluminal coronary intervention, smart bracelet recognized the notice and recorded time of the decision of interventional procedure (13:19). Meanwhile, the doctor introduced fully the benefit and risk of the operation to the patient and families, smart bracelet recognized the doctor’s talk time and recorded the time of starting the informed consent (13:19), and the doctor notified the staff to start catheterization room, intelligent bracelet recorded the time of starting the catheter laboratory (13:19), then identified the doctor’s antiplatelet drug dosing instruction, recorded the time of first administration of antiplatelet drug (13:21). After the patient informed and agreed to sign a consent form, the doctor uploaded informed consent

![Figure 1](image1.png)  
**FIGURE 1.** The workflow of CPC in China and how our system is involved in the workflow. It illustrated the standard process of how an AMI patient was treated in CPC in China. The blue column is the key time points a doctor should record. The words or phase between the column illustrated how our system was involved in the workflow. AMI indicates acute myocardial infarction; CPC, chest pain center.

![Figure 2](image2.png)  
**FIGURE 2.** A schematic diagram of the smart CPC illustrated the workflow of the smart CPC and related equipment. CPC indicates chest pain center.
A Smart Chest Pain Center for Better Quality Control

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www.critpathcardio.com  |  165

to system, and intelligent bracelet recorded the time of signing of the informed consent (13:24). When the interventional staff noticed CCU doctor catheterization laboratory had been activated, bracelet identified the instruction and recorded the time of the activation of the catheter laboratory (13:45). Then the patient is transferred to the catheterization laboratory, BLE base station positioned to the intelligent wristband, recorded the time of the patient arrival at catheter laboratory (13:46), when patient arrived door of catheterization laboratory. After entering catheterization room, smart bracelet recognized doctor anticoagulant drugs dosage instruction and recorded the time of first administration of anticoagulant drug (13:48), then the doctor started to implement interventional surgery, the interventional cardiologist posed characteristic motion at the end and start of puncture, respectively, wristband identified the characteristic motion and recorded the time when the puncture starts (13:49) and the time of puncture success (13:54), then bracelet recognized insertion of the angiography catheter of the characteristic actions and the angiography completion of the characteristic actions, recorded angiography starting time (13:55) and angiography ending time (13:56), respectively, when performer inserted the angiography catheter. Whereupon the performer expansion balloon catheter, passed guidewire, the wristband recognizes the characteristic image of the balloon dilation, recorded time of the first balloon dilation time (13:59). After the operation, the patient left the catheter room, and the smart bracelet recorded the procedure ending time (14:29). The emergency treatment of chest pain was completed; the patient returned the bracelet and was transferred to CCU for further treatment.

LIMITATION

Although we have verified that the system can smoothly run in our center, but we still need more data and study to elucidate the accuracy and reliability of the system.

CONCLUSIONS

In the present study, we constructed a CPC with some advanced information techniques, which provide automatic recording of the key time points and patient position tracing. If the solution can be generalized to the world, we believed that we could obtain more accurate, unified, and traceable data, which will significantly improve the quality control of CPC and prognosis of the AMI.

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DISCLOSURES

Nothing to declare.

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