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# Development and application of electronic crossmatch in Dongguan city

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## ABSTRACT

Electronic crossmatching is a computer-assisted technology used to confirm if red blood cell (RBC) blood products are suitable for the intended recipient. In addition to mainland China, electronic crossmatching has been used in many countries. Here we have developed an electronic crossmatching system for clinical application. The primary and advanced system of electronic crossmatching was developed, the primary system includes ABO and RhD blood group antigens, and the advanced system includes 18 common RBC group antigens. We completed *in-situ* and online testing; the system was installed in six general hospitals in Dongguan for clinical application. A total of 31,941 crossmatches were performed by both electronic and serological crossmatching from July 1st, 2015 to April 30th, 2016. The electronic crossmatch shows to be more powerful than the serological crossmatching, if RBC blood products and recipients were compatible when electronic and serological crossmatch completed, all blood were issued to clinic. In this condition, no case of hemolytic transfusion adverse reaction occurred. In conclusion, the electronic crossmatch system can be used in transfusion medicine and is capable of reducing laboratory workload and costs, as well as improving transfusion safety.

**Keywords:** transfusion medicine, electronic crossmatch, ABO group, RhD

## INTRODUCTION

Electronic crossmatching is an electronic method used to confirm that a blood sample is suitable for transfusion to the intended recipient by using validated software logic to determine compatibility. The electronic crossmatch system has already been implemented in many developed counties, such as the United States, Denmark, Holland, Norway, Britain, Canada and Australia, and will be available imminently in other countries, namely Japan, Hungary, New Zealand, Turkey, and Italy[1-5]. Electronic crossmatching is based on the rapid development of information technology, transfusion medicine and patient identification. In addition to the Hong Kong special administrative region, until now, the electronic crossmatching system has not been implemented in mainland China. In order to validate electronic crossmatching system developed for the needs of China, we retrospectively reviewed and analyzed the results of blood-group identification on 180,000 donors and 100,000 recipients. The accuracy rates of ABO/RhD groups of donors and recipients we found to all be 100%[6-7]. The positive rates of irregular antibodies screening for donors and recipients were also analyzed, with irregular antibody panel cells being used to identify specificity. However, the positive rate of irregular antibody screening for donors was low in Dongguan city, which is lower than other regions in China[6]. Accordingly, the aim is to confirm all recipients suitable for implementing the electronic crossmatch system.

## MATERIALS AND METHODS

### ABO group and antibody screening methods

The electronic crossmatching system was devel-

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oped in Dongguan Blood Center, leading on from our previous study[8]. To investigate the feasibility of its clinical application, electronic crossmatching was confirmed by the serological tests. The electronic crossmatching system includes two levels: the first (the primary system) is in line with the AABB guide[9]; the second (the advanced system) is based on the primary system, but with an expanded application scope.

ABO group methods included forward typing and reverse typing. Forward typing was performed by mixing 1 drop of 5% red blood cell (RBC) suspension and 1 drop of monoclonal anti–A or anti–B reagent (Shanghai Blood Biotechnology Co., Ltd., Shanghai, China) in two tubes, respectively, centrifuged at 1,000 rpm for 1 min, and the agglutinate intensity was checked. Reverse typing was performed with the standard A, B and O RBC reagents (prepared by the Blood Transfusion Laboratory) to identify natural anti–A or anti–B in plasma.

Donor irregular antibody screening was tested by the Sanquin automatic blood group identification system, irregular screening cells and microcolumn gel method (all provided by Sanquin, Amsterdam, Holland). Irregular screening cell group antigen included: C, D, E, c, e, Cw, f, V, K, k, $Kp^a$, $Kp^b$, $Js^a$, $Js^b$, $Fy^a$, $Fy^b$, $Jk^a$, $Jk^b$, $Le^a$, $Le^b$, $P_1$, M, N, S, s, $Lu^a$, $Lu^b$, $Xg^a$. Specific identification was performed when irregular antibody screening was positive. The results of irregular antibody screening on blood donors were printed on the blood label. Irregular antibody screening of recipients (in hospital) were performed by incubating 1 volume (25 μL) of 1 percent reagent RBCs in low–iron–strength saline with an equal volume of donors´ or recipients´ plasma, then the anti–globulin microcolumn gel technique (DiaMed, Switzerland) test was applied.

## ABO/RhD group information database

Recipients´ general information was extracted from the hospital information system (HIS), which included name, gender, age, birth date, ethnicity, personal ID, clinical ID, ward number, bed number, transfusion history, medical history, pregnancy and clinical diagnosis. The recipient´s information database in combination with the electronic crossmatching system were used to extract automatically; personal ID, clinical ID and group information which included ABO/RhD history records and detailed information such as irregular antibodies and transfusion adverse reaction history records. The donors´ information contained donation code, ABO/RhD group, irregular antibody screening and specificity.

## ABO/RhD group validation for the first–time transfusion recipients

For the first–time recipient, two samples were collected at different times for ABO/RhD groups´ identification, which were implemented by different technicians or different laboratories; if only one sample was available, two different technicians and two different identification reagents were needed. The results of twice obtained ABO/RhD groups´ identification were typed into system and only if the two results were consistent, the electronic crossmatch system was allowed to perform next step.

## ABO/RhD group validation for repeated transfusion recipients

For the repeat transfusion recipient, where only one sample was needed to validate the ABO/RhD group, the current results were required to be consistent with their history records. If the history records were not consistent with the results of the sample, the system should display a warning message and the recipient would be regarded as a first–time recipient, in which case required there collection of the two samples for ABO/RhD group validation (according to ABO/RhD group validation for the first–time transfusion recipients). Flowcharts for electronic crossmatch and blood issue can be seen in ***Fig.1.***

## The advanced system and match rate

Eighteen common RBC group antigens, including: E, e, C, c, M, N, Mur, S, s, $Jk^a$, $Jk^b$, $Fy^a$, $Fy^b$, added $P_1$, $Le^a$, $Le^b$, K, and $Di^a$ were added to the donors´ and recipients general information in the advanced system. The match rate of ABO/RhD groups between donor and recipient should be 100%, according to ABO/RhD groups´ compatibility in the primary system, so if ABO/RhD groups were not compatible, the match rate would show as zero, and the electronic crossmatch system would terminate. In the advanced system, ABO/RhD match rates were set to 60%, and the 18 common RBC group antigens were set to 40%. The match rate of each antigen was calculated according to ***Table 1***. If one of the common antigens were the same between donor and recipient, the antigen match rate would be added to the ABO/RhD match rate. The more common antigens that were completely matched between donor and recipient, the higher the match rate. If all of the common antigens were same between donor and recipient, the match rate was 100%. Therefore, the higher the match rate was, the safer the transfusion. The advanced system was not allowed to issue a RBC blood product that contained any posi–

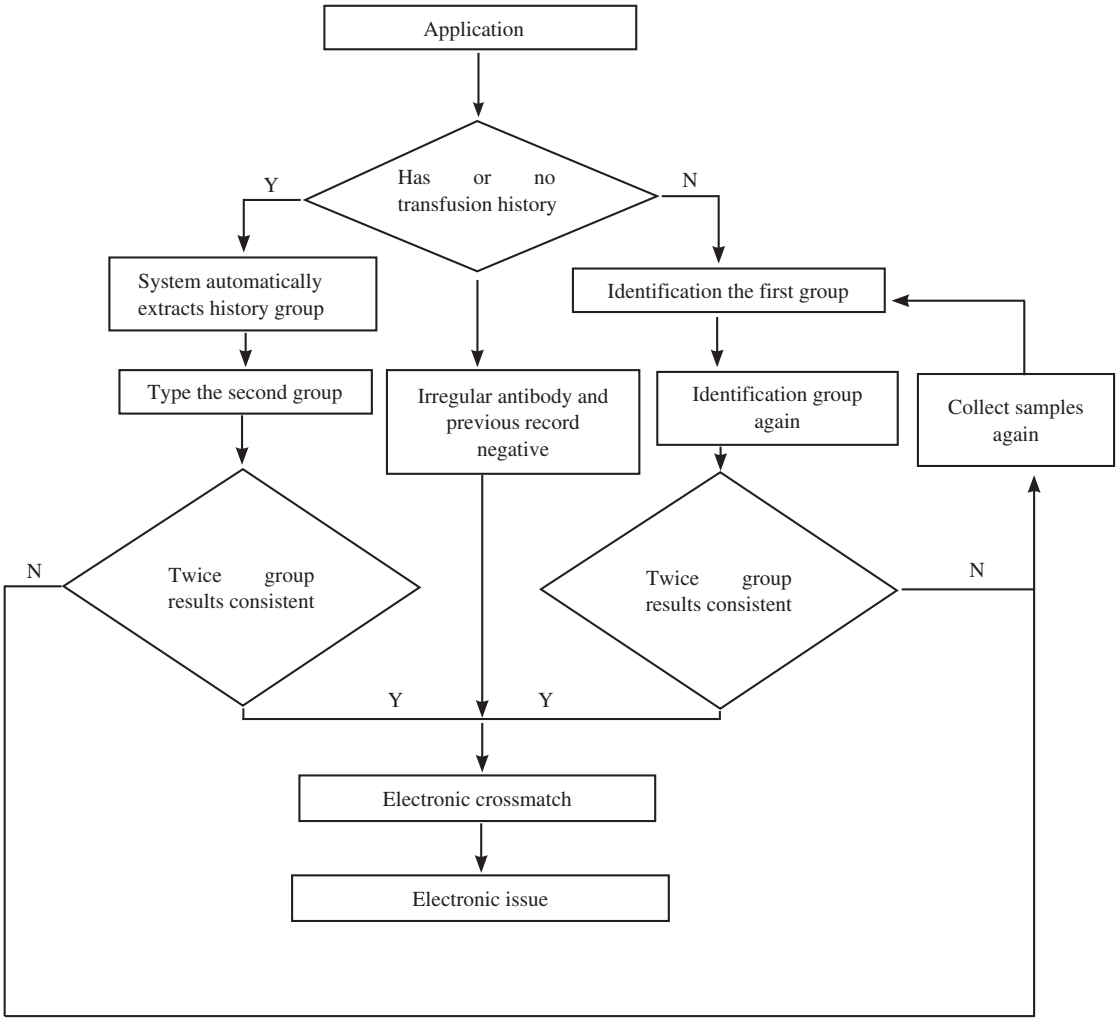


***Fig.1*** **Flowcharts for electronic crossmatch and issue**

***Table 1*** **Match rate of 18 common antigen blood groups in Chinese population**

| Antigen | Frequency(%) | Weight of blood group | Weight of antigen | 40% weight of antigen |
|---|---|---|---|---|
| E | 93.00 | 0.5440 | 22.2858 | 8.9143 |
| e | 39.00 | 0.5440 | 9.3456 | 3.7383 |
| C | 47.00 | 0.5440 | 11.2627 | 4.5051 |
| c | 96.00 | 0.5440 | 23.0047 | 9.2019 |
| M | 108.00 | 0.1836 | 8.7346 | 3.4938 |
| N | 82.60 | 0.1836 | 6.6803 | 2.6721 |
| S | 95.00 | 0.1836 | 7.6832 | 3.0733 |
| s | 5.90 | 0.1836 | 0.4772 | 0.1909 |
| Mur | 9.60 | 0.1836 | 0.7764 | 0.3106 |
| P1 | 74.80 | 0.0544 | 1.7924 | 0.7170 |
| Lea | 48.00 | 0.1309 | 2.7677 | 1.1071 |
| Leb | 42.00 | 0.1309 | 2.4218 | 0.9687 |
| Jka | 73.00 | 0.0323 | 1.0387 | 0.4155 |
| Jkb | 76.00 | 0.0323 | 1.0813 | 0.4325 |
| Fya | 99.00 | 0.0204 | 0.8896 | 0.3559 |
| Fyb | 11.00 | 0.0204 | 0.0988 | 0.0395 |
| K | 1.00 | 0.0017 | 0.0007 | 0.0003 |
| Dia | 7.00 | 0.0085 | 0.0262 | 0.0105 |

tive antigens against the alloantibodies displayed in the recipient. If irregular antibodies were present in any blood products against any one of the 18 common antigens (as above), it was not allowed to be issued to the clinic. The match rates were calculated using the following methods: ① Total match rate = 60%+ the common antigens match rate; ② The remaining antigen match rate = antigen frequency × group system weight × coefficient(0.4405) × 40%, where the group system weight was the ratio of irregular antibody frequency in the group system and the total positive rates of irregular antibody. Antigen frequency was referenced to the Chinese population. Irregular antibody frequency in the group system was calculated by the meta-analysis of the literature reports [8].

## Models of transfusion matches

Match models were from all RBC blood products in blood bank, which were divided into A/RhD$^+$, B/RhD$^+$, AB/RhD$^+$, O/RhD$^+$, A/RhD$^-$, B/RhD$^-$, AB/RhD$^-$, and O/RhD$^-$. The electronic crossmatching

system calculated the match rates for all RBC blood products automatically, and RBC blood products information was displayed according to the match rate.

If the match rate was higher than 60% in the advanced system, the units were allowed to issue. Only a senior operator can issue in cases of emergency, cases when items such as RhD positive RBC blood products may be given to RhD negative recipients, or A or B group washed RBC blood products could be given to AB group recipients.

The electronic crossmatch system was completed according to above design, followed by *in-situ* verification (simulating various conditions) and on-line verification (connected to the network, according to the actual situation). After verification, the system was installed in hospitals of Dongguan city for clinical trials.

This study was approved by the Ethics Committee of the Dongguan Blood Center and all aspects of the study complied with the Declaration of Helsinki.

## RESULTS

ABO/RhD groups, irregular antibody screening and serological compatibility tests were performed before transfusion in all hospitals in Dongguan. All blood is required to be issued by the transfusion information management system (TIMS), which has been installed in all hospitals of Dongguan city, and is able to provide certain information for on-line ordering. Crossmatch tests were performed the day before surgery or completed within 30 minutes in emergency. The blood issuing time was shortened helping staff overcome stress. The crossmatch to transfusion rate (C/T) was 1.6, with about 1% of units being discarded each year due to expiry.

The crossmatch rate of ABO/RhD groups was 100% based on compatibility. Irregular antibodies in recipients and donors must be negative, ideally with negative results from recipients being obtained within 3 days of the transfusion. In cases of its being longer than 3 days, the electronic crossmatch system is set to regard the recipient as not having completed the irregular antibody screen and the system will terminate. If the recipient irregular antibody shows negative, but their history records showed positive, a warning message will display immediately after the current result is typed into system, and the recipient would be regarded as irregular antibody positive.

A total of 31,941 crossmatches were performed by both electronic and serological crossmatch from July 1st, 2015 to April 30th, 2016 in Dongguan. About 42,876 units of RBC of compatible blood products were issued after the completion of electronic crossmatch and serological tests. Because of the elimination of serological crossmatch testing, the cost of reagents and consumables were saved. The electronic crossmatch system showed more powerful than serological tests, and there were no cases of hemolytic reaction.

## DISCUSSION

All serological testing aims to guarantee transfusion safety, by predicting the compatibility before transfusion (through simulation tests *in vitro*) and detecting incompatibilities of ABO/RhD groups or irregular antibodies.

In the early 1980s, only 58 cases showed positive for clinically significant irregular antibodies out of 1 million serological tests[9, 10]. Around this time it was reported that serological testing consisted of 11 processes from a given blood bank to recipient´s vascular system with a total of 66 steps being involved. Although every step seemed to be very simple[10, 11], the chances of error was very high due to the complicated process of sample handling. If an irregular antibody was found negative, immediate centrifugation would be the only method needed and the antiglobulin method could be omitted[1,5]. This strategy was published in the 15th edition of the AABB[11,12], however, the immediate centrifugation method has been found to fail to completely rule out ABO/RhD incompatibility. The electronic crossmatch system has the advantage of reliably checking the ABO/RhD compatibility between recipients and donors, suggesting that the electronic crossmatch system is safer than the immediate centrifugation method[3]. The electronic crossmatching system has also been reported to reduce the rate of expired blood products and also to reduce the crossmatch workload by 65% compared with serological testing[4]. Compared with serological crossmatching, electronic crossmatching can save 30 min each time, greatly improving efficiency[12,13].

In the present study, we developed a new electronic crossmatch system with two designs: a primary system for ABO/RhD compatibility, which was only applied in Dongguan and an advanced system which tests for 18 common RBC group antigens. Based on the results from 31,941 crossmatch tests, results showed no hemolytic reaction. In emergency, the O/RhD$^-$ RBC blood products could be transfused into anyone recipient, RhD positive RBC blood products could be transfused to RhD negative recipients, and A or B group washed RBC products could be transfused to AB group recipients and RBC products could be issued in two minutes. The system was more economical than serological testing. From our study of 31,941

electronic crossmatches, when compared with serological crossmatch, we estimated a saving of ¥638,820 yuan, based on the cost of ¥20 yuan for each serological crossmatch, plus total of 479,115 minutes would be saved if 15 minutes of serological crossmatch were omitted.

Compatibility is the key procedure before transfusion. It needs to be accurate in the identification of each recipient. Blood services and hospitals have established suitable online resources and are able to access transfusion management system data. However, regional laws allowing for the implementation of electronic crossmatching pose the biggest question.

In conclusion, electronic crossmatching can reduce workload, lower costs, improve transfusion safety and subsequently replace serology crossmatching.

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