ORIGINAL ARTICLE

# Virtual blood banking in Hong Kong


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**Objective** To review our experience in virtual blood banking for intra-operative transfusion in Hong Kong.

**Design** Retrospective study.

**Setting** Three major acute hospitals and a specialised centre for joint replacement surgery with installation of an Operating Theatre Blood Transaction System.

**Patients** Patients undergoing surgery under anaesthesia and requiring intra-operative transfusion for the period from the implementation of the system in individual institutes (Queen Elizabeth Hospital: June 1997; Princess Margaret Hospital: May 2001; Queen Mary Hospital: October 2009; and Hong Kong Buddhist Hospital: December 2010) till September 2011.

**Results** Under the system, 58 923 units of red cells were released intra-operatively for 18 264 patients (11% of the total number of blood units issued by the blood banks in these institutes during the study period). About 1% of them (613 units) entailed unmatched red cells given to 183 patients for emergency transfusions during surgery. The mean time required for the issue of the first unit of red cells was less than 1 minute. A total of 1231 units of red cells were returned unused after being released. Among them, 95 units were deemed unfit for re-issue because they had left the temperature-monitored blood storage refrigerators in the operating theatres for more than 30 minutes. There was no delay in transfusion or postponement of surgery due to problems or downtime of the Operating Theatre Blood Transaction System.

**Conclusion** Our experience has shown that our virtual blood banking system was efficient and effective, and helped ensure that the right patient received the right amount of the right blood at the right time. The system can be implemented either locally in the same hospital with a central blood bank, or in a more remote and networked site without a nearby supporting blood bank.



**Key words**
Blood banks; Blood grouping and crossmatching; Blood transfusion; Intraoperative care; Medical informatics

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**New knowledge added by this study**

- Virtual blood bank is the remote, electronically controlled and self-service blood release system. It is efficient, effective, and error-free for providing electronically crossmatch-compatible blood for scheduled operation and unmatched blood for emergency intra-operative transfusion. Furthermore, it has been proven safe for implementation in three major acute hospitals with organ transplant and trauma management services, and also in a more remote and networked site without an on-site supporting blood bank.

**Implications for clinical practice or policy**

- Our experience supports further expansion of virtual blood banking system in the public hospitals where a networked IT platform is in existence. It may also encourage blood banks in the private sector to explore the possibility of utilising electronic crossmatch and most important of all, the possibility of a virtual blood banking system in the future.

## Introduction

The term "virtual transfusion service laboratory" first appeared in an editorial in the journal *Transfusion* in 1997,[1] in relation to the report on a remote electronic blood release system by Cox et al.[2] In the same year, we had also developed a computer software system that was termed Operating Theatre Blood Transaction System (OTBTS) that allowed self-service ordering and on-demand, on-site release of computer crossmatch–compatible red cells in the operating theatre (OT), far away from the blood bank at Queen Elizabeth Hospital

(QEH), Hong Kong.[3] It was then further developed to provide unmatched red cells for emergency transfusion.[4] Subsequently, several groups have also published their experience in virtual blood banking (Table).[2-6] The OTBTS is basically an extension of the computer crossmatch[7] and blood bank porter service. It enables online ordering and prompt release of computer crossmatch–compatible red cells by non-laboratory personnel for intra-operative transfusion and also controlled release of unmatched red cells during emergency surgery, through a web-based and networked information management system. In this report, we reviewed our experience in the utilisation, benefits, and safety of such a virtual blood bank in three major acute hospitals and a specialised centre for joint replacement surgery without an on-site blood bank.


## 香港的虛擬血庫

**目的** 回顧我們在香港推行虛擬血庫在術中輸血方面的經驗。

**設計** 回顧研究。

**安排** 在香港設有手術室血液處理系統的三家大型急症醫院及一家專門進行關節置換手術的醫療中心。

**患者** 於上述四家醫療機構中自手術室血液處理系統開始運作（即伊利沙伯醫院：1997年6月、瑪嘉烈醫院：2001年5月、瑪麗醫院：2009年10月、香港佛教醫院：2010年12月）直至2011年9月期間，所有進行麻醉手術並需要術中輸血的病人。

**結果** 結果顯示在研究期間，經手術室血液處理系統一共提供58 923個紅細胞單位給18 264名病人（佔這些機構同期所提供紅細胞單位的11%）。其中包括約1%（613個）未配對的紅細胞單位，給予183名進行緊急手術的病人。由要求提取到發出第一個紅細胞單位所需時間平均少於1分鐘。未經使用而退回的紅細胞單位有1231個，其中95個因從保存血液的溫度控制冷藏裝置取出超過30分鐘而不能重用。研究期間沒有因手術室血液處理系統故障引致供血或手術延誤。

**結論** 我們的經驗顯示虛擬血庫是可行及高效的，能及時給有需要的病人提供合適的血液。這系統可以在設有血庫的醫院推行，也可在位置偏遠而沒有中央血庫但有資訊網絡連繫的醫院中運作。


## Methods

Our OTBTS was a Windows-based (Microsoft, Redmond [WA], US) software system developed by the Information Technology Division of the Hospital Authority (HA) in collaboration with the Department of Pathology at QEH. It was an extension of computer crossmatching and provided a cyber highway that allowed online ordering and remote, real-time, self-service release of compatible red cells by the OT nurses, for patients with a negative antibody screen. For patients with a positive antibody screen or special blood requirements such as cytomegalovirus-negative red cells, the OT nurse was alerted and the blood ordering had to go through the central blood bank.

The system made use of barcode technology to ascertain staff and patient identity and minimise transcription errors, and also included built-in computer logic with pre-defined transfusion rules to ensure red cell compatibility. It was networked through the supporting platform of the Laboratory Information System of the HA. The system was validated on-site and field-tested according to international guidelines[8] and was implemented at QEH on 16 June 1997.[3] It was further expanded to incorporate the computer logic for ordering and release of unmatched red cells for transfusion during emergency operations in 2002.[4] If emergency intra-operative transfusion was required, group O unmatched red cells were issued if the patient's blood group was not known. Once the patient's blood group was available, group-identical (not necessarily group O) unmatched red cells were to be released. A unique feature of the system was that once the patient's blood sample was processed by the blood bank, a real-time indication of the expected time for completion of the Type and Screen (T&S) and availability of computer-crossmatched red cells for patients with a negative T&S was given.[4] This was calculated from the time that the blood sample was received and the promised turnaround time of the T&S. This facilitated deciding whether to wait for the T&S result and thus use crossmatched red cells for emergency transfusion.

TABLE. The development of virtual blood banking systems[2-6]

| Virtual blood bank | Country/city | Implementation | Reference |
|---|---|---|---|
| Remote electronic blood release system | Australia | 1995 | Cox et al,[2] 1997 |
| Operating theatre blood transaction system | Hong Kong | 1997 | Wong et al,[3] 1999 |
| Virtual blood banking—unmatched module | Hong Kong | 2002 | Wong and Kwan,[4] 2005 |
| Electronic remote blood issue | United Kingdom | 2005 | Staves et al,[5] 2008 |
| Remote-controlled automatic blood storage | Italy | 2006 | Pagliaro and Turdo,[6] 2008 |

The system was adopted by two other major acute hospitals, the Princess Margaret Hospital (PMH) in May 2001 and the Queen Mary Hospital (QMH) in October 2009. It was extended to the specialised centre for joint replacement surgery at the Hong Kong Buddhist Hospital (HKBH) in December 2010; this hospital does not have an on-site blood bank, and its transfusion service is supported by QEH. The web-based connection between QEH and HKBH is maintained through the Wide Area Network Ethernet. Since its institution, OTBTS has not undergone any major changes, apart from the tagging of a compatibility label on the blood unit with the addition of a verification label step in QMH, in order to comply with the accreditation requirement of the College of American Pathologists. Only red cells are stored in the OTs, except at PMH where whole blood with low haemolysin titres may also be kept.

The electronic process control of the OTBTS provided an accurate audit trail of the procedures undertaken by both non-laboratory personnel in the OT and blood bank staff. In this report, we reviewed the utilisation of such online requests and electronic release of red cells for intra-operative transfusions and evaluated its performance including turnaround time and wastage rate at sites where OTBTS was installed. All clerical, software, and transfusion incidents associated with the system were also examined.

## Results

The catchment areas of the three clusters (Kowloon Central, Kowloon West, and Hong Kong West Clusters accorded with the geographical cluster designation by the HA), where the three major acute hospitals are situated, serve a total population of about 3 million Hong Kong inhabitants. The blood banks of these three hospitals are located in buildings far away from their respective OTs. Much time is therefore wasted arranging the porter service for transportation of red cells if transfusion is needed during an operation and the procedure has to be repeated if additional red cells are required (Fig 1a). The OTBTS allows prompt on-site release of red cells by the OT nurses (Fig 1b).

From June 1997 to September 2011, a total of 58 923 units of red cells were released to 18 264 patients through the OTBTS in the three hospitals (QEH: 39 249 units; PMH: 12 244 units; QMH: 7107 units) and the specialised centre for joint replacement surgery (HKBH: 323 units). They accounted for 11% of the total number of blood units issued by the three blood banks serving these four institutions. Among them, 613 units were unmatched red cells (group unknown and thus group O: 440 units; group-identical: 173 units) and were given to 183 patients for emergency intra-operative transfusions. The mean time for the issue of the first unit of red cells, as measured from the time of entry of the patient's identity into the system in these four institutions ranged from 30 to 51 seconds (with the joint replacement centre showing the longest turnaround time, probably reflecting the less frequent utilisation of the system). Only 1231 units of red cells (including 227 units of unmatched red cells) were returned unused after being released. Among them, 95 units were deemed unfit for re-issue because they had left the temperature-monitored blood storage refrigerators in the OT for more than 30 minutes. No adverse transfusion incident or delay in transfusion or postponement of surgery was reported due to any problems or downtime of the OTBTS. Several instances of hardware problems were reported, particularly in the early phases of implementation, but did not affect transfusion care. There was one incident of malfunctioning of the blood storage refrigerator and remote alarm system, resulting in wastage of the stored red cells. As appropriate contingency measure was in place, the incident did not result in any delay in transfusion or postponement of surgery. In the three blood banks, the blood stock reserved for patients undergoing surgery was reduced by 20 to 45%.[3] It was only necessary to re-stock the inventory 3 to 4 times a week.

A review of blood bank records for the three major acute hospitals showed that the hospital-wide crossmatch-transfusion (CT) ratio dropped from 1.5-1.6 to <1.2 for QEH and PMH after the implementation of the OTBTS. The average CT ratio of QMH was 1.13 after the use of a computer-generated list of all blood units available in the blood bank inventory for self-service blood ordering by OT nurses in 1995,[9] with further reduction to 1.02 after the implementation of the OTBTS. Blood wastage was maintained at a very low level (QEH: 0.57%; PMH: 1.4%; QMH: 1.9%) after the implementation of the OTBTS even with the adoption of the '30-minute rule'.[10]

## Discussion

Blood transfusion is a high-risk procedure because of the complexity of its many, often manual procedures and the involvement of multiple personnel from different departments during the process. Virtual blood banking has benefited from the advantages of information and communication technologies to ascertain the accuracy of the patient, the specimen, and the blood unit identification. It has also enhanced the ability to trace personnel and improve system security.[11] The built-in computer logic and manual process constraints in the design of such a remote blood release system will guide the selection of appropriate red cells, and thus minimise transfusion risks. Extending the computer crossmatch beyond the blood bank to the point of

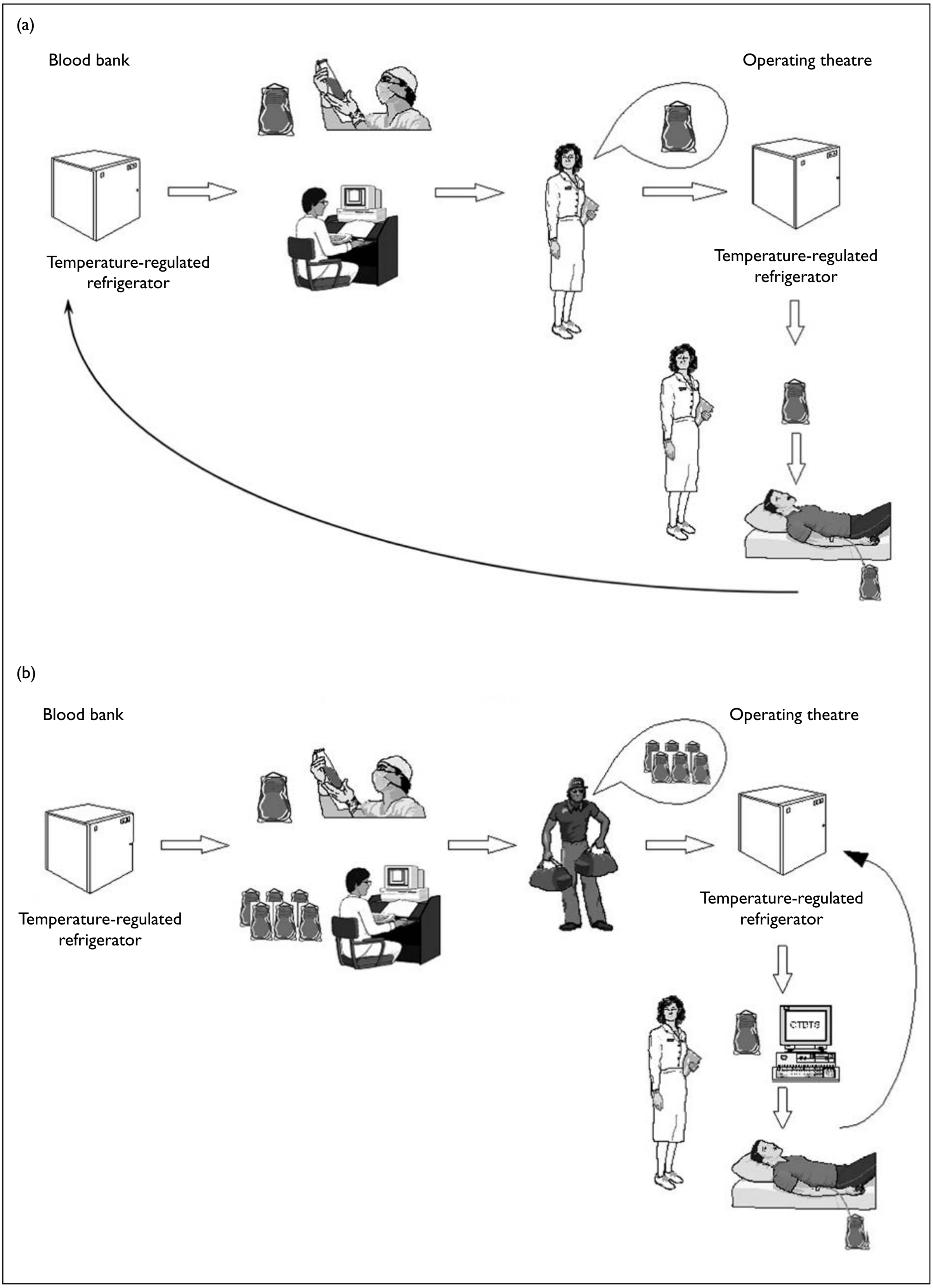


**FIG 1. The blood order-release-delivery process before and after implementation of the Operating Theatre Blood Transaction System (OTBTS)**

(a) In the past, the nursing staff had to go to the blood bank located in another building to collect red cells for transfusion during operation. The journey had to be repeated if more blood was required. (b) After the implementation of the OTBTS, appropriate numbers of blood units of different ABO groups are transferred and stored separately in designated compartments of blood storage refrigerators in the operating theatre. The nursing staff can go to the nearby station and issue red cells when transfusion is needed during operation

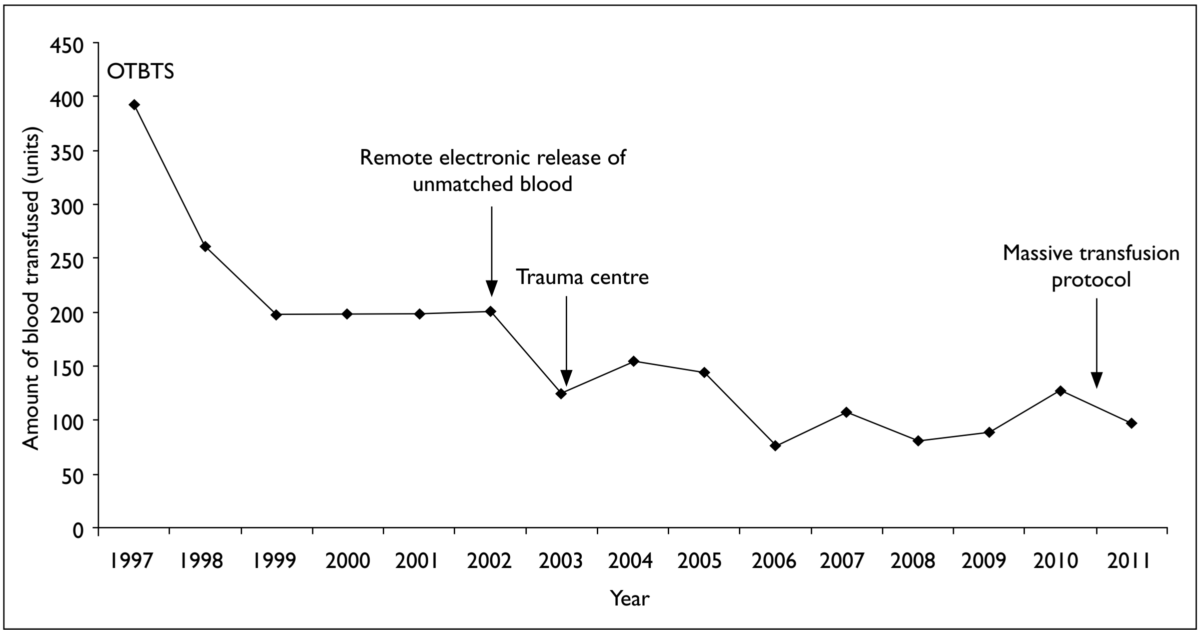


FIG 2. Unmatched blood for intra-operative emergency transfusion in Queen Elizabeth Hospital (January 1997 to September 2011)
OTBTS denotes Operating Theatre Blood Transaction System

care can ensure a prompt and unlimited supply of compatible red cells and allow real-time inventory monitoring and flexible management, with early stock replenishment. Furthermore, it provides an audit trail for critical procedures in the transfusion process via the electronic and paperless documentation system. There are also substantial savings in manpower as it reduces the number of phone calls and does not require an on-demand and impromptu porter service for transportation of red cells. Thus, it can alleviate the stress of staff (both nursing and technical) and avoid miscommunication, particularly when it involves emergency transfusion. It is useful during the management of massive intra-operative haemorrhage, as matched or unmatched red cells can be delivered almost simultaneously to multiple patients.

Furthermore, our study has confirmed the safety and efficiency of virtual blood banking for intra-operative transfusion for both scheduled and emergency surgery in a large number of patients and at different sites. The OTBTS has shortened the time required for the delivery of red cells to the OT for intra-operative transfusion from a mean of 30 minutes[3,12] to less than 1 minute. It has helped reduce the CT ratio and blood wastage rate, while still keeping to the '30-minute rule' for the return of issued but unused red cells required by international guidelines.[10] Previously it was shown that in QEH, the requests for unmatched red cells and the amounts transfused, and the return rate of issued unmatched red cells had decreased significantly (almost 30%) after the implementation of the OTBTS.[3] A similar experience was shared by the other two major acute hospitals where the system was installed. Such a low utilisation of unmatched red cells for an autonomous, readily accessible and self-controlled blood order-release system has persisted even after the provision of a trauma centre and a massive transfusion protocol (Fig 2). Furthermore, about a quarter of patients might require extra red cells (ie more than originally anticipated for the type of operation) during surgery and benefit further from the system because of the ready availability of red cells in the OT.[4] Our study demonstrated the application of a virtual blood banking system in three different major acute hospitals and also in a non-acute hospital without an on-site blood bank. It also attested to the safety and wastage reduction characteristics of remotely monitored and autonomous release of unmatched red cells for emergency intra-operative transfusions in different hospitals with different clinical management protocols and practices.[4]

Thus, virtual blood banking has been shown to save workload, reduce staff stress, ensure prompt blood availability, and enhance transfusion safety in Hong Kong.[3,4] It is important to remember, however, that the safety and efficacy of such a system are built upon stringently validated and carefully maintained hardware systems, together with well-trained and conscientious staff for necessary, but minimal, manual-handling activities. The system is particularly applicable in Hong Kong where the population is mostly Southern Chinese, with a phenotypic homogeneity in relation to red cell antigens. Thus, only about 3.7% of our patients have a positive antibody screen[13] and cannot receive the full benefit of the system because designated red cells have to be given. Some commercially designed virtual blood banking systems are now available in the market, which have incorporated a kiosk-based system (blood-vending machine) for controlled delivery of red cells, as it is no longer necessary for OT nurses to select red cells of the appropriate blood group from the electronically controlled blood storage refrigerator.[5,6] Other and perhaps more 'imaginative' enhancements include the use of intelligent mobile phone applications such as barcode scanning, text messaging (eg blood counts) and voice alert (eg special requirements), or even biometric recognition to ensure correct blood sampling from the right patient.

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