

A Review of Procedures Involved in Human Umbilical Cord Blood Banking and Transplantation

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Abstract

Cord blood hematopoietic stem cells are widely used as an alternative source for hematopoietic stem cells transplant. Increasing rate of patients who need hematopoietic stem cells transplant and many advantages of cord blood in comparison to bone marrow hematopoietic stem cells, have promoted banking of cord blood units. Cord blood banking requires accurate steps in donor selection, cord blood collection, processing, cryopreservation and finally screening and testing of the units. The main limitation of umbilical cord blood transplantation is cell dose and resolving this limitation is vital in avoiding frequent problems in hematopoietic stem cells transplant. Transplantation of more than one unit and ex vivo expansion of umbilical cord blood units, decrease these limitation. Furthermore, the international standard guidelines have been published by the Foundation for the Accreditation of Cellular Therapy (FACT)-NetCord to improve the quality of units and simulation of cord blood banks activities. This review presents a general overview on cord blood banking and related activities and its improvement during last two decades.

Keywords: Blood banking, cord blood, hematopoietic stem cells.

Introduction

Today, hematopoietic stem cells transplant (HSCT) is used as a treatment method in a variety of malignancies as well as benign, inherited and dysplastic disorders^{1,2}. The main source of hematopoietic stem cells (HSCs) is bone marrow, but these cells are also present in peripheral blood and Umbilical Cord Blood (UCB) in a lower count^{3,4}. Since the first successful UCB transplant in 1988 to a patient with Fanconi's anemia, the UCB has been known as an alternative source for HSCT⁵. The special properties of UCB-HSCs including immediate availability of CB units, low risk of donation for mothers and infants, less HLA restriction for donors, potentially reduced risk of Graft Versus Host Diseases (GVHD), low risk of viral infection and more expression of proliferation and expansion transcript factors, make it as a preferable source for HSCT⁶⁻¹⁰. These properties caused much attention to harvest and storage of CB units and CB banks were established all over the world^{11,12}. Some of the CB banks are private and store the CB units for the same family, public CB banks collect

and store the donated CBs for allogeneic HSCT, and hybrid CB banks do both activities. Because of increasing rate of diseases that need HSCT and limited HLA identical donors, there are many patients who do not find HLA matched units. Therefore, the necessity of expanding CB banks is clear. The main objective in CB banking is to store high quality units for successful HSCT, so, they work under strict quality control rules. Donor selection is an important step to select safe units. For volume reduction some manual or automatic procedures are used and high cell recovery is desired¹³. After the CB unit volume reduction, Total Nucleated Cell (TNC) count, CD34 absolute count, viability tests and Colony Forming Unit (CFU) assay are performed on separated buffy coats¹⁴⁻¹⁶. CB banks usually define cut offs for some criteria, for instance; on TNC and CD34+ cell counts and viability tests^{17,18}. If the processed unit is qualified, all the infectious screening tests and HLA typing are done and the HLA results will be added to the database¹⁹. The aim of the present study is to provide an overview

of CB banking procedures involved in human UCB banking and transplantation as well as current issues in resolving some limitations.

Donor selection

Donor selection is an important step in CB bank's activity. The quality of units requires extensive and accurate donor information. Healthy donor mothers are informed that UCB donation is voluntary and consent is obtained. The family medical history is reviewed and CB from single birth, low-risk mothers, with normal obstetric practices is selected. Some excluding criteria are as follows: presence of congenital abnormalities, hematologic or immune deficiency disorders, inherited coagulopathies, metabolic disorders, history of high risk sexual behavior, drug abuse and blood transfusion within 12 months before delivery²⁰. Mother blood samples also should be obtained for infectious disease screening, including; microbial culture, cytomegalovirus, Syphilis, Hepatitis virus B and C, Human Immunodeficiency Virus 1 and 2 and some other tests according to the local policies. There are some documents showing that following these strict criteria leads to collection of only about 30% of units^{20,21}. Furthermore, other studies have indicated that only 10-15% of banked cord blood units contain sufficient TNC and CD34+ cells for adult HSC transplant^{22,23}.

Cord blood collection

The CB units are collected by trained staff. The cord blood is harvested from venous cord in utero or ex utero, after careful disinfection of the umbilical cord, in order to reduce risk of contamination. Venous cord blood flows by gravity into a CB bag containing adequate volume of anticoagulant reagent. In some centers open CB collection is used, but the rate of contamination is more than closed method (14% VERSUS 4%)²⁴. The labeled cord blood and mother units as well as detailed documents are transported to the CB bank in appropriate temperature for the processing²⁵.

Cord blood selection for volume reduction and processing

Some collected CBs do not contain adequate cells; therefore, the cord blood volume, TNC count, and CD34+ cell count are performed on aliquots separated from CB units before volume reduction.

The cut off for each criterion is characterized by the bank and usually are different within the banks.

Volume reduction

In order to save the space and decrease the CB bank costs, plasma and red blood cells are removed from CB units. In volume reduction processing, a method that leads to more TNC recovery and also cost effectiveness is preferred²⁶. There are two main methods, manual and automatic. In both methods usually Hydroxyethyl Starch (HES) is used for better RBC sedimentation, as Robinstein et al., have showed²⁷. HES can recover 98% of CFUs. Other experiments using density gradient centrifugation, gelatin and HES sedimentation have resulted in low loss of HPCS²⁷. In the manual method, after adding HES 6% to CB in a ratio of 1:4, buffy coat is separated by two step centrifugation²⁸. The mixture of plasma and HES, also sediment RBCs are transferred to the satellite bags and buffy coat is collected to a freezing bag, usually adjusted to 20 ml. The automated instruments have also been designed for buffy coat separation in a close system. The mixture of CB and HES connect to a single use kit, containing a chamber or a bag that is housed in a device or instrument and buffy coat layer is formed under centrifugation. An optical sensor controls buffy coat fraction separation of the unit. In automated methods usually a two step centrifugation is performed and finally buffy coat is shifted to the freezing bag in a closed system. In some studies the TNC recovery by automated methods has been reported to be as high as 77% to 78%^{13,18}, whereas, in manual method it rises to more than 80%^{29,30}. Furthermore another investigation has pointed to CFU recovery of 98% in manual method²⁷. All together, the rate of recovery in manual method is slightly higher than automated method, but processing in a closed method with lower contamination is an important advantage of automated techniques.

Cryopreservation

For cryopreservation of UCBs, the units are placed in a mixing and cooling device to add cryopreserving solution containing Dimethyl Sulfoxide (DMSO) and dextran 40 (1:1). The separated buffy coat is then mixed with DMSO in a mixture of 4:1 and 2 reference samples are drawn from the unit. For the better cell freezing,

a control rate freezer is used. This instrument decreases the unit temperature from 4°C to -100°C in a programmed rate³¹. Until the screening test results are gained, units are saved at gas phase of liquid nitrogen, and if there are no any positive test results, they will be transferred to a liquid phase for long term storage. The cooling rate of units, also protectant reagent are the main factors governing the survival of HSCs, so, many studies have been performed to optimize cryopreservation protocols^{32,33}.

Cord blood testing

All the infectious diseases screening tests are performed on the plasma fraction and ABO and hemoglobinopathies are detected on sediment RBCs. TNC count of the main product is evaluated using automated cell counter and nucleated RBCs are excluded. The CD34+ absolute count is calculated using flow cytometry according to ISHAGE protocol. Cell viability testing by trypan blue dye exclusion or DNA fluorescent dyes have been studied^{25,34}. CFU assay in a semisolid culture media is then used to characterize the quality of CB units. The HLA typing for the allele A and B and DRB1 is performed on DNA extracted from buffy coats using a PCR based method and in some cases sequence based typing is carried out^{35,36}.

Cord blood transplantation

At first UCBT was only performed in sibling donors, even with the HLA mismatch at one of the three loci. After a short time UCBTs with unrelated donors were reported with high rate of engraftment and low rate of GVHD³⁷. Several studies have focused on correlation of engraftment with CB volume, TNC, CD34+ cell dose, and CFU assay to define some criteria for the successful transplantation^{17,38-40}.

New insights in Cord blood banking

The most important limitation of CB units is cell dose, that implies low potential for widespread use of CB units since a threshold of 2×10^7 TNC/kg of recipient body is required for successful transplantation⁴¹, many methods have been used for ex vivo expansion of UCB HSC^{42,43}. The culturing of UCB for expansion has showed that committed progenitors and immature cells, also LTC-ICs were substantially amplified without any effect on proliferative potential⁴⁴. The previous

studies focused on CD34+/CD38- HSCs expansion, because they highly proliferate in the presence of cytokine cocktails and generate more and contain long telomeres⁴⁵. Separation of this population needs ex vivo manipulation of UCB units that increase the risk of contamination. However, recent studies have demonstrated that the whole buffy coat expansion causes short recovery of BM after UCBT. Today using two CB units compensate the low cell dosage⁴⁶. In order to minimize the GVHD, transfusion of donor T cells to the recipients, and decreasing the risk of GVHD, haploidentical mesenchymal stem cells are added to the UCB units to increase the HSCs homing and lower the immunological responses^{47,48}. In addition to CB expansion, ex vivo megakaryocyte differentiation of HSCs to overcome late platelet recovery after CBT has been performed^{49,50}. Genetic manipulation of UCB-HSCs, because of their self renewability and differentiation into progenitor cells, is an interesting therapeutic source in patients suffering from diseases such as: Fanconi's anemia, cycle cell anemia, thalassemia and some other hematologic disorders. Several investigations have described successful introduction of specific genes into UCB-HSCs⁵¹. Finally, unrestricted somatic stem cells derived from UCB, reside in an early differentiation state, and after an appropriate stimulation treatment, can display a wide differentiation capacity in vitro and in vivo⁵².

Conclusion

UCB transplantation has been known as a viable source of HSCs for patients with malignant and non malignant hematopoietic disorders. To collect and storage these valuable HSC sources, many UCB banks have been established worldwide. Banking of UCB units gives a chance to patients who do not have a HLA matched sibling or unrelated stem cell donor to find a ready HSC source in a short time. Storage of all valuable units needs large spaces and has lead to introduction of some procedures to reduce the unit's volume and consequently presentation of automated cell separation methods that are helpful in CB bank activities. As the CB banking cost is high, it is important to bank the qualified units; therefore, there have been some efforts to improve the size and quality of CB banks to store more and safer units.

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