

# Characteristics of Collected Umbilical Cord Blood at Hai Phong Medical University Hospital and Vietnam National Institute of Maritime Medicine in 2024

Pham Thi Loc<sup>1\*</sup>, Truong Van Hieu<sup>1</sup>, Do Nguyen Mai Anh<sup>1</sup>, Tran Minh Hoang<sup>1</sup>, Pham Thuy Quynh<sup>1</sup>, Tran Thi Anh Duong<sup>1</sup>, Bui Van Hieu<sup>1,2</sup>, Nguyen Truong Son<sup>3</sup>, Nguyen Van Khai<sup>1,2</sup>

## ABSTRACT

**Objective:** Determining the characteristics of collected umbilical cord blood (UCB) at Hai Phong Medical University Hospital and the Vietnam National Institute of Maritime Medicine and evaluation of the relationship between risk factors and the volume of UCB in 2024. **Materials and Methods:** A prospective cross-sectional study was conducted on 172 UCB samples collected between September and November 2024. **Results:** The average collected UCB volume was  $87.6 \pm 24.4$  ml. Of the 172 samples, 152 (88.4%) met quality standards, while 20 (11.6%) were excluded due to low volume, clot formation, or microbial contamination. Total nucleated cells collected  $80.78 \pm 49.14$  ( $\times 10^7$  cell), with 71.7% recovery. Lymphocytes is  $48.7 \pm 59.5$  ( $\times 10^7$  cell), recovering 87.4%. Red blood cells are  $0.089 \pm 0.054$  (T/L), with 1.8% recovery. Platelets are  $683 \pm 351.6$  ( $\times 10^7$ ), achieving 55% recovery. Maternal factors such as age, delivery method, and delayed cord clamping influenced UCB quality. In utero collection yielded higher total nucleated cell (TNC) counts and CD34+ cells compared to ex utero methods. **Conclusion:** the result provide an information for UCB banking and processing, demonstrating effective preservation of high nucleated white blood cells and lymphocytes, eliminates almost all red blood cells, and retains a portion of platelets, making it suitable for regenerative medicine and immunotherapy applications.

**Keywords:** Umbilical Cord blood, Cord blood bank, Hematopoietic stem cells, total nucleated cells, cord blood quality.

<sup>1</sup> Hai Phong University of Medicine and Pharmacy, Vietnam  
<sup>2</sup> Hai Phong Medical University Hospital  
<sup>3</sup> Vietnam National Institute of Maritime Medicine

## \* Corresponding author

Pham Thi Loc  
Email: [ptloc@hpmu.edu.vn](mailto:ptloc@hpmu.edu.vn)

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## INTRODUCTION

Umbilical cord blood (UCB) is a valuable source of hematopoietic and mesenchymal stem cells, used in the treatment of various malignant diseases [1,2]. The field of UCB banking has flourished with advancements in understanding the unique biological properties of UCB, contributing to successful transplants. UCB is especially beneficial due to its high compatibility with

human leukocyte antigens (HLA), which reduces the risk of graft-versus-host disease (GVHD) and offers an important solution for patients without compatible HLA donors, particularly in minority ethnic groups [2].

The quality of UCB is crucial for treatment outcomes and depends on several factors, with the collection process being key. An optimal UCB collection requires precise timing and technique to maximize blood volume and preserve key cell

populations like total nucleated cells (TNCs) and CD34+ hematopoietic stem cells, which are essential for transplant success. Maternal, neonatal, and obstetric factors, such as maternal age, weight, delivery method, and gestational age, also influence UCB quality. Additionally, UCB collection, processing, and storage methods must be carefully optimized to maintain cell viability and function, ensuring the highest standards for transplant procedures [3,4].

This study aims to analyze the characteristics of umbilical cord blood collected at Hai Phong Medical University Hospital and the Vietnam National Institute of Maritime Medicine in 2024, focusing on key parameters such as volume of cord blood, total nucleated cell count and factors influencing these characteristics, including collection methods, maternal and neonatal factors, and delivery methods.

## METHODS

### Study Objectives

From September 2024 to November 2024, 172 umbilical cord blood samples were collected at Hai Phong Medical University Hospital and the Vietnam National Institute of Maritime Medicine. All samples included complete maternal, neonatal, and obstetric data and pre-processing collection results.

*Inclusion Criteria:* Voluntary UCB donors aged over 18, without chronic or acute diseases, and who agreed to participate in the study.

*Exclusion Criteria:* Individuals diagnosed with blood disorders (e.g., anemia, Thalassemia, Leukemia) or infectious diseases such as HIV, HBV, HCV, etc.

### Methods

*Study Design:* A cross-sectional descriptive study. All women delivering

either vaginally or via cesarean section at the Vietnam National Institute of Maritime Medicine and Hai Phong Medical University Hospital were included in the study using a convenience sampling method.

### Collection and Processing of UCB

UCB collection was carried out immediately after birth to ensure sample quality and sterility. First, the umbilical cord near the newborn was clamped and cut by a doctor or midwife. The remaining portion attached to the placenta was clamped to prepare for blood collection. In vaginal deliveries, the designated area on the umbilical cord was disinfected three times with Betadine 10% solution to maximize bacterial elimination. For cesarean deliveries, this disinfection step may be simplified based on the circumstances, but if there is any risk of contamination, the umbilical cord surface is carefully disinfected. A syringe attached to a blood storage bag containing an anticoagulant was used to collect blood from the umbilical vein. Blood flowed into the bag by gravity until the flow stopped, at which point the needle was safely removed. The blood bag was stored at room temperature and transported to the processing room within 48 hours to maintain sample stability [5].

In the processing room, the UCB volume (excluding anticoagulant) was accurately measured (in milliliters), and a small portion (1-2 ml) was cultured to check for bacterial or fungal presence. Maternal information, including age and screening results for infectious diseases, was recorded. Neonatal information at birth, including gestational age, sex, birth weight, and delivery method, was noted. Obstetric information included delivery method

(vaginal or cesarean section), family presence, and whether the cord was clamped quickly or slowly. Data was collected on the time and method of blood collection and time from collection to processing [5,9].

### Data Processing

Data was entered into Excel and analyzed using GraphPad Prism 10.0. Descriptive statistics were performed with quantitative variables presented as mean  $\pm$  standard deviation (SD), and qualitative

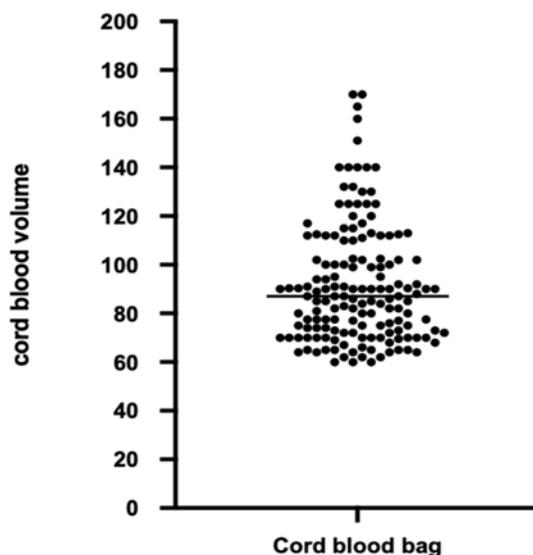
variables as percentages. Statistical analysis included t-tests, with significance levels  $p$ . Logistic regression was used to assess relationships between factors, with odds ratios (OR) and 95% confidence intervals (CI) provided.

### Ethical Considerations

This study was approved by the Ethics Committee of Hai Phong University of Medicine and Pharmacy (Protocol 13/IRB\_HPMU, August 26, 2024) and adheres to its data confidentiality policies.

## RESULTS

### Distribution of Collected Umbilical Cord Blood Volume



*Chart 1. Distribution of Umbilical Cord Blood Volume.*

The initial average volume of umbilical cord blood (excluding anticoagulant) collected was  $87.6 \pm 24.4$  ml. The majority of the umbilical cord blood volumes collected ranged from 65 to 110 ml, with the most common average volume falling between 70 and 90 ml (Chart 1).

### Causes for Discarding Umbilical Cord Blood Bags

*Table 1. Overall results and causes for discarding umbilical cord blood bags after collection*

	n	Percentage (%)
<b>Total Umbilical Cord Blood Collected</b>	172	100%
<b>Number of valid UCB samples</b>	152	88.4%
<b>Number of discarded UCB samples</b>	20	11.6%
<b>Volume of CB &lt; 60 ml</b>	8	4.7%

	<b>n</b>	<b>Percentage (%)</b>
<b>Presence of clots</b>	3	1.7%
<b>MCV UCB &lt;85 fl</b>	1	0.6%
<b>TNC &lt; 60 x 10<sup>7</sup></b>	4	2.3%
<b>Others (missing information, delayed collection, etc.)</b>	0	0
<b>Positive for bacterial and fungal cultures</b>	3	1.76%
<b>Infected with HBV, HCV, HIV, CMV</b>	1	0.6%

Of 172 UCB samples, 152 (88.4%) met standards, while 20 (11.6%) were discarded. Reasons included low volume of CB (<60 ml) in 8 samples (4.7%), clots in 3 (1.7%), MCV <85 fl in 1 (0.6%), low TNC (<60 × 10<sup>7</sup> cells) in 4 (2.3%), bacterial/fungal contamination in 3 (1.76%), and HBV infection in 1 (0.6%).

### Characteristics of Maternal Factors and the Delivery Process

*Table 2. Characteristics of maternal factors and the delivery process when collecting umbilical cord blood*

	<b>n</b>	<b>Mean ± SD</b>	<b>Min</b>	<b>Max</b>	<b>%</b>
<b>Mother's Age</b>	152	29.8 ± 4.92	19	40	
<b>Weight</b>	152	62.5 ± 3.27	52	73	
<b>MCV</b>	152	106.2 ± 4.6	85.3	112	
<b>HGB</b>	152	132.9 ± 20.68	111	177	
<b>Number of Delivery</b>	152				
<i>First time</i>	64				42.1%
<i>≥ 2</i>	88				57.9%
<b>Delivery method</b>	152				
<i>Cesarean</i>	70				46.1%
<i>Vaginal delivery</i>	82				53.9%
<b>Family presence at birth</b>	152				

	<b>n</b>	<b>Mean ± SD</b>	<b>Min</b>	<b>Max</b>	<b>%</b>
<i>Family present</i>	21				13.8%
<i>No family present</i>	131				86.2%
<b>Umbilical cord clamping</b>	152				
<i>Slow clamping</i>	118				77.6%
<i>Fast clamping</i>	34				22.4%

Based on Table 2, the characteristics of the mothers show an average age of 29.8 ±4.92 years, ranging from 19 to 40 years. Weight: On average 62.5 ±3.27 kg, ranging from 52 to 73 kg. MCV (mean corpuscular volume): On average 106.2 ±4.6 fl, ranging from 85.3 to 112 fl. The average hemoglobin concentration was 132.9 ±20.68 g/L, ranging from 111 to 177 g/L. Number of deliveries: First delivery: 64 cases (42.1%), Second or more deliveries: 88 cases (57.9%). Delivery method: Cesarean section: 70 cases (46.1%) and Vaginal delivery: 82 cases (53.9%). Family presence at birth: 21 cases (13.8%) with family present, and no family present: 131 cases (86.2%). The rate of slow umbilical cord clamping: 118 cases (77.6%) and fast umbilical cord clamping: 34 cases (22.4%).

### Characteristics of factors for collecting UCB

*Table 3. Characteristics of UCB collection factors*

	<b>n</b>	<b>Mean ± SD</b>	<b>Percentage (%)</b>
<b>Collected by</b>	152		
2 staff members	98		64.5%
1 staff member	54		35.5%
<b>Collection method</b>	152		
Intrauterine	85		44.1%
Extrauterine	67		55.9%
<b>Collection time</b>	152		
<10 minutes	88		
≥ 10 minutes	64		
<b>Time from collection to processing</b>	152		

	<b>n</b>	<b>Mean ± SD</b>	<b>Percentage (%)</b>
< 6h	122		80.3%
≥ 6h	30		19.7%

Based on Table 3, we can see that the workforce involved in collecting umbilical cord blood, with collection done by 2 staff members, accounts for 64.5%, while collection by 1 staff member accounts for 35.5%. The method of collecting umbilical cord blood intrauterine accounts for 44.1%, while extrauterine collection accounts for 55.9%. The collection time of <10 minutes accounts for 57.9%, while collection time of ≥10 minutes accounts for 42.1%. The time from collection to processing of <6 hours accounts for 80.3%, while the time from collection to processing of ≥ 6 hours is lower at 19.7%.

### Characteristics of newborns

*Table 4. Characteristics of newborns during UCB collection*

	<b>n</b>	<b>Mean ± SD</b>	<b>Percentage (%)</b>
<b>Gestational age</b>	152	38.9 ± 1.08	
<b>Birth weight</b>	152	3.4 ± 2.95	
<b>Newborn gender</b>	152		
<i>Male</i>	67		44.1%
<i>Female</i>	85		55.9%

Based on Table 4 regarding the characteristics of newborns, the average gestational age is 38.9 ±1.08 weeks. The average birth weight is 3.4 ±2.95 kg. In terms of gender, 44.1% of the newborns are male, while 55.9% are female.

### Characteristics of umbilical cord blood before and after processing

*Table 5. Characteristics of umbilical cord blood before and after processing of UCB*

	<b>Pre-treatment</b>	<b>Post-treatment</b>	<b>Recovery efficiency</b>
<b>Number of nucleated cells ( x 10<sup>7</sup>)</b>	112.68 + 55.14	80.78 ± 49.14	71.7%
<b>Lymphocyte ( x 10<sup>7</sup>)</b>	55.7+ 72.4	48.7 ± 59.5	87.4%
<b>Red blood cell (T/L)</b>	3.83 + 0.58	0.089 ± 0.054	1.8%
<b>Platelets (x 10<sup>7</sup>)</b>	1243 +416.4	683 ± 351.6	55%

Table 5 shows UCB characteristics before and after processing. Total nucleated cells decreased from 112.68 ±55.14 to 80.78 ±49.14 (×10<sup>7</sup>), with 71.7% recovery. Lymphocytes dropped from 55.7 ±72.4 to 48.7 ±59.5 (×10<sup>7</sup>), recovering 87.4%. Red blood cells fell from 3.83 ±0.58 to

0.089 ±0.054 (T/L), with 1.8% recovery. Platelets declined from 1243 ±416.4 to 683 ±351.6 (×10<sup>7</sup>), achieving 55% recovery.

**Correlation of certain characteristics with low UCB collection volume under 80ml**

*Table 6. Correlation of certain characteristics during UCB collection with low UCB collection volume under 80ml*

Characteristics	OR	95% CI	p
<b>Fetal weight</b>			
< 3000 grams	2.8	1.4 - 4.8	1
≥ 3000 grams			
<b>Gestational age</b>			
< 38 weeks	3.7	2.0 - 6.9	< 0.001
≥ 38 weeks			
<b>Mode of delivery</b>			
Cesarean section	1.4	0.7 - 2.9	0.08
Normal delivery			
<b>Family presence at delivery</b>			
Family present	3.1	1.2 - 5.8	0,005
No family present			
<b>Collection method</b>			
Intrauterine	1.9	1.1 - 3.2	0.02
Extrauterine			
<b>Collection time</b>			
< 10 minutes	1.2	0.6 - 2.2	0.4
≥ 10 minutes			
<b>Cord clamping</b>			
Delayed cord clamping	2.8	1.5 -5.2	0,001

Characteristics	OR	95% CI	p
Immediate cord clamping			

Univariate logistic regression analysis identifies several factors significantly associated with low UCB volume (<80 ml). Low birth weight (<3000 g) increases the risk 2.8 times (95% CI: 1.4–4.8,  $p = 0.001$ ), and preterm birth (<38 weeks) raises the risk 3.7 times (95% CI: 2.0–6.9,  $p < 0.001$ ). Presence of a family member triples the risk (95% CI: 1.4–4.8,  $p = 0.005$ ), while in-utero collection doubles it (95% CI: 1.1–3.2,  $p = 0.02$ ). Delayed cord clamping increases risk nearly 3 times (95% CI: 1.5–5.2,  $p = 0.001$ ). No significant associations were found for collection time or delivery mode ( $p > 0.05$ ).

## DISCUSSIONS

In this study, all research samples were collected UCB for the study. The collected UCB will undergo the process of isolating nucleated cells and sorting CD34+ cells. These cells will be stored long-term for use in genome editing technology and regenerative medicine. Thus, the goal of the research group is to obtain the maximum number of nucleated cells and CD34+ cells possible, functioning as a tissue bank. Therefore, our UCB quality standards are quite high and adhere to international guidelines, following recommendations from international organizations such as AABB and Net-Cord, ensuring the optimal usage when needed for regenerative medicine, stored without limitations on the gestational age or maternal age [5,6].

According to our study, the initial volume of UCB (excluding anticoagulant) collected was on average  $87.6 \pm 24.4$  ml, with most UCB samples having a collection volume in the range of 65 - 110 ml. The minimum volume accepted for UCB collection in our study is equivalent to some community UCB banks globally but is lower than the UCB bank at the Central Institute of Hematology and Blood Transfusion, which requires 80ml [6]. Reuther et al. (2022) analyzed 10,054 autologous cord blood samples in Germany and found the collection volume followed a

normal distribution, with 60–70 ml being the most common range [7]. The sample rejection rate at the Central Institute's UCB bank is very low, accounting for 57.4% [4,7]. In our study, 88.4% of samples met the standard, reflecting high collection and processing quality. Of the 20 rejected samples, 4.7% were due to low blood volume (<60 ml), 2.3% had low total nucleated cell counts (< $60 \times 10^7$  cells), and 1.7% were clotted, often linked to cesarean sections. One sample was rejected for low mean corpuscular volume (MCV < 85 fl), and 1.76% tested positive for bacterial or fungal contamination. Only one sample (0.6%) was rejected for Hepatitis B, with no rejections due to administrative or timing issues, highlighting efficient management.

Community UCB banks, such as the Central Institute of Hematology and Blood Transfusion, set standards for mothers aged 18-35 years, with gestational age >36 weeks, birth weight >2600g, and UCB volume >80 ml (excluding anticoagulant). The Guangzhou Cord Blood Bank collects from mothers aged 18+ with gestational age >34 weeks, while the Iran National Cord Blood Bank processes samples >60 ml [4,6,7]. High standard achievement rates reflect effective collection and processing, though issues like low volume, clots, and contamination require further improvement.

To assess factors affecting UCB quality, we analyzed maternal characteristics and delivery processes. The mothers' average age was  $29.8 \pm 4.92$  years (19–40), a safe range for UCB studies due to lower risks of congenital abnormalities. Their average weight was  $62.5 \pm 3.27$  kg (52–73), indicating healthy pregnancies. Our study results are consistent with domestic research findings regarding age and weight [8,9].

Regarding the biological characteristics of the cord blood sample: MCV (Mean Corpuscular Volume) had an average value of  $106.2 \pm 4.6$  fl, within the acceptable range, ensuring good sample quality for stem cell collection. HGB (Hemoglobin) averaged  $132.9 \pm 20.68$  g/L (ranging from 111–177 g/L), reflecting good maternal health and suitable cord blood quality. As for obstetric history, 42.1% of the mothers were primiparous, and 57.9% had delivered two or more children. This balanced ratio helps assess cord blood quality from mothers with varying obstetric histories. Our study has 53.9% of births were vaginal deliveries, while 46.1% were cesarean sections. This is consistent with previous studies, as vaginal deliveries typically provide better conditions for collecting high-quality cord blood [10,11]. Family presence during birth was reported in only 13.8% of cases, while 86.2% did not have family members present. Delayed cord clamping was used in 77.6% of cases, which is more common than immediate clamping (22.4%). This aligns with medical recommendations, as delayed clamping helps ensure the best blood volume for the newborn, although in some emergency cases, immediate clamping may be necessary [10,11].

Factors affecting the collection process include manpower, collection method, collection time, and waiting time for

processing. The use of two staff members (64.5%) for collection demonstrates good support for the process, reducing risks and increasing technical efficiency. However, coordinating personnel for UCB collection remains a challenge. As for the collection method, ex vivo collection accounted for 55.9%, which is suitable for vaginal births as it is easier to perform. In contrast, in utero collection (44.1%) is preferred in cesarean sections, as it allows for optimal sample volume collection and reduces the risk of contamination. Most samples were collected within 10 minutes (57.9%), ensuring sample quality, while 42.1% of cases took more than 10 minutes, which could increase the risk of clot formation, though only one sample was rejected due to clotting. In our process, we typically perform a two-phase collection. The time from collection to processing: Samples processed within 6 hours accounted for 80.3%, indicating good management of the process and preservation of cell quality. The remaining 19.7% of samples had a processing time of 6 hours or more due to overnight collections, which resulted in a longer storage time before processing. Our study results are consistent with research findings regarding risk factor [11,12]

The recovery efficiency of leukocyte was 71.7%, indicating that the process was effective in preserving most nucleated cells, ensuring quality for regenerative medicine applications. Regarding lymphocyte count, the recovery efficiency was 87.4%, demonstrating good preservation of lymphocytes, which are critical for immunotherapy applications. As for red blood cells, the recovery efficiency was very low at 1.8%, indicating that nearly all red blood cells were removed. This is a positive result, as red blood cells are unnecessary and could interfere with stem cell or immune

applications. Platelet recovery efficiency was 55%, reflecting partial preservation of platelets, though a significant number were discarded. This may be appropriate depending on the application, especially if the focus is on other cell types. Overall, the data show that the processing procedure has been highly effective in preserving important components like nucleated cells and lymphocytes while significantly removing unnecessary components like red blood cells, ensuring the quality of the final product. Our study results are the same data with research of Hang and Duyen research findings regarding collected cell procedure [7,8].

The collection of UCB is influenced by many factors throughout the delivery process, from maternal and neonatal characteristics to the collection process itself. According to the results shown in Table 07, the main factors affecting low cord blood volume (<80ml) include the relationship between weight and gestational age: fetal weight <3000 grams and preterm (<38 weeks) were strongly associated with low collection volumes (OR = 2.8), with statistical significance. This can be explained by the fact that smaller or preterm infants often have poorly developed umbilical circulation, resulting in less cord blood. This is a factor to consider when selecting candidates for cord blood collection [10 -13].

Another issue is delayed cord clamping. The Ministry of Health currently advocates for delayed clamping to benefit the newborn, but this practice reduces the amount of cord blood collected, as much of the blood is transferred back to the infant's body [5,9]. Therefore, this must be considered when aiming to collect large volumes of cord blood. In some emergency cases, immediate clamping may be indicated to collect more UCB. Additionally, in utero collection may

lead to lower volumes compared to ex utero collection. This could be due to the two-phase collection process in our study, which may differ from other studies. Another key factor is the presence of family members during the birth, which increases the risk of low UCB collection, as the process of cutting the cord can delay the UCB collection. Other factors, such as collection time and cesarean section delivery, did not show a clear link to low UCB volumes. Overall, the results provide an important information for the cord blood collection process and collecting TNC for regenerative medicine.

## CONCLUSIONS

This study demonstrates the effectiveness of UCB collection and processing for regenerative medicine, with an acceptance rate of 88.4%. Key factors such as gestational age, fetal weight, and delayed cord clamping significantly impact UCB volume. High recovery rates for nucleated cells (71.7%) and lymphocytes (87.4%) highlight the quality of the samples. These findings provide an information for UCB banking and enhancing cell therapy applications.

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