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Biobanking in the Modern Era: Infrastructure, Ethical Challenges, and the Emerging Role of Umbilical Cord Stem Cells

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Abstract: Biobanks are facilities that preserve biomaterials with high-quality and long-term preservation. To research the pathophysiology of illness, establish biomarkers for diagnosis, and work with human tissue to potentially uncover targeted therapeutic medicines, biological materials, and data are routinely captured and stored in this system. In addition to providing the best possible management of patient biomaterials for research and diagnostic purposes, biobanks serve as a unifying and complementary element across clinical and core disciplines. Implementing all these dynamics while abiding by international guidelines is crucial. Biobanking involves ethical concerns, as well as the information technology (IT) systems, collection, and preservation of materials. Financing is also necessary to cover the cost of the infrastructure. In the last few decades, umbilical cord (UC) biobanking has grown exponentially and has become a revolutionary concept in advancing the medical industry. Compared with other adult stem cell sources for clinical transplantation, primitive hematopoietic stem cells (HSCs) and mesenchymal stem cells (MSCs) are abundant in UC blood and tissues. However, in addition to creating efficient consent procedures to enable the potential therapeutic use of UC-derived stem cells and to build a sizable global UC-biobanking network, it is imperative to enhance and standardize UC processing, preservation, quality assurance protocols, and regulatory frameworks.

Keywords: biobanking; biospecimens; cryopreservation; umbilical cord; hematopoietic stem cells; mesenchymal stem cells.

1. Introduction

The practice of preserving biological samples and associated data for use in medical and health research is known as biobanking. This is a crucial component of biomedical research, serving as repositories for a wide range of biological specimens and the associated data. These repositories have the potential to completely transform our understanding of health and illness by providing researchers with priceless tools to study the molecular, genetic, and environmental determinants of human health. The field of biobanking has expanded and enhanced medical research methodology. This field has advanced due to the growth of omics science (genomics, transcriptomics, proteomics, and metabolomics) and the ability to create large digital databases containing vast volumes of patient clinical information [1]. Biobanks are therefore essential in the era of precision medicine, which relies on the analysis of samples alongside clinical data. Gathering and preserving biological samples analyzed with healthcare,

occasionally epidemiological information, including implementing a governance framework and process that safeguards the rights of donors and stakeholders, and using privatization to protect donor anonymity and a re-identifiable procedure for particular conditions where clinically pertinent data is accessible and possibly given to the patient, are some of a biobank's fundamental duties [2]. As data collection, sample management, and the use of biological material for investigation have advanced, so too has the need to protect patients and to adhere to safeguards for human subjects, as well as requirements for anonymity and secrecy when exchanging samples. Medical professionals, biological researchers, nurse practitioners, bioethicists, and other professionals collaborate with modern biobanks, which function as complex infrastructures to guarantee the right to use human biological materials. The biobank workflow is shown in Figure 1 [3].

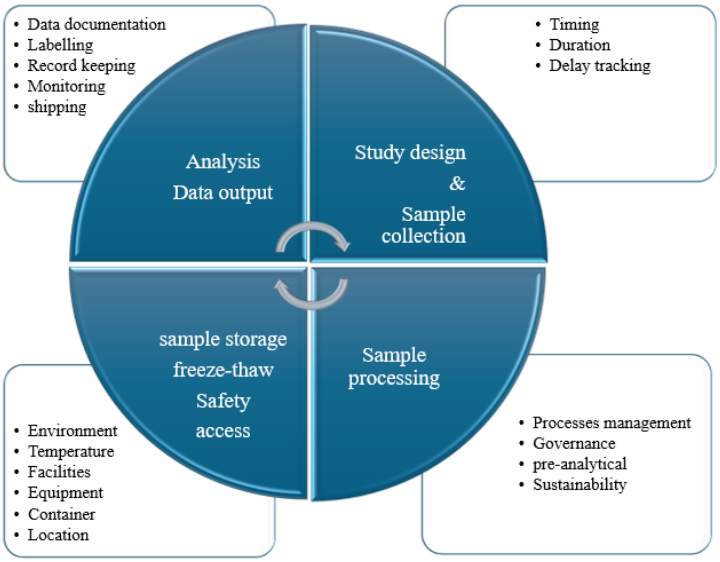

Figure 1. Workflow of biobanks.

1.1. Recent trend in global biobank growth.

The global biobanks market size was estimated at USD 81.29 billion in 2024 and is projected to reach USD 126.69 billion by 2030, growing at a CAGR of 7.85% from 2025 to 2030, as depicted in Figure 2. High investments in R&D for advanced therapies, such as regenerative medicine, personalized medicine, and cancer genomic studies, are among the driving factors [4].

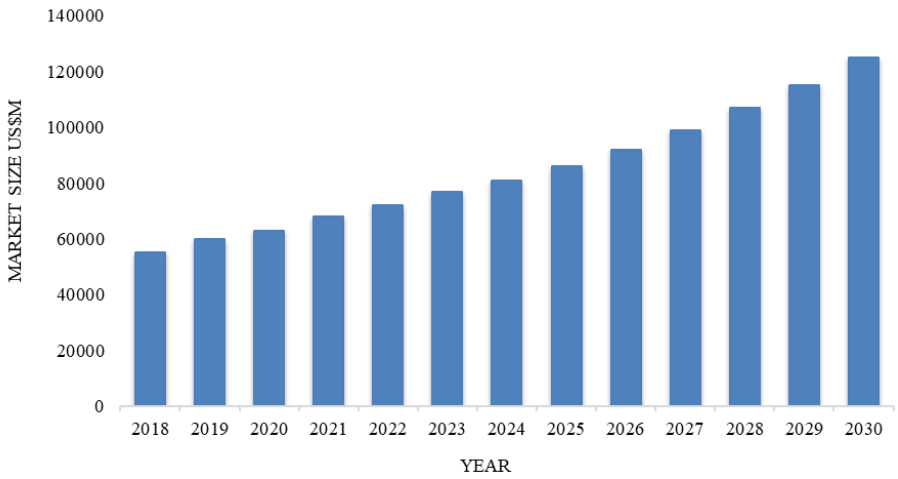

Figure 2. Global biobanks market share.

2. Biospecimens in Biobanking

Biobanks, which store biological specimens, are vital institutions that hold a range of samples obtained from contributors. Research projects ranging from understanding diseases to developing innovative remedies depend on these specimens. In order to improve healthcare outcomes, biosamples are essential instruments for study on genetic variants, biomarkers, pathophysiology, and therapy. Some common biospecimens are shown in Figure 3. Blood samples, obtained via venipuncture or finger pricking, are rich in information and include genetic material (DNA and RNA), hormones, biochemical indicators, and blood cell counts. They are used for research, illness tracking, and diagnostics in a variety of medical specialties [5]. With tiny tissue samples for microscopic analysis from organs or lesions, a pathologist can detect cellular abnormalities, tissue architecture, and molecular markers linked to diseases, including cancer, infections, and autoimmune disorders, thanks to the crucial diagnostic information these samples offer. They can be collected by endoscopic procedures, surgical excision, and needle biopsies. Saliva and oral swabs include a variety of oral cavity bacteria, proteins, enzymes, and cells. These non-invasively obtained specimens are used to analyze the oral microbiota, identify oral infections, and conduct oral health research. They also provide information about systemic diseases such as autoimmune disorders, diabetes, and cardiovascular disease. Oral swabs are used for forensic analysis and genetic testing. The kidneys produce urine as a waste product that contains hormones, electrolytes, metabolic byproducts, and other materials filtered from the blood. Urine samples, which are routinely collected for urinalysis, are used to assess kidney function, hydration levels, and the presence of conditions such as proteinuria, kidney stones, and urinary tract infections in research studies, drug screening, and pregnancy testing. The waste product that is ejected from the gastrointestinal tract is called stool or feces. Undigested food, water, germs, viruses, and other materials can be found in stool samples for diagnostic purposes, such as screening for colorectal cancer, assessing digestive function, and detecting gastrointestinal infections [6]. Additionally, stool samples are used to investigate inflammatory bowel diseases, digestive problems, and gut flora.

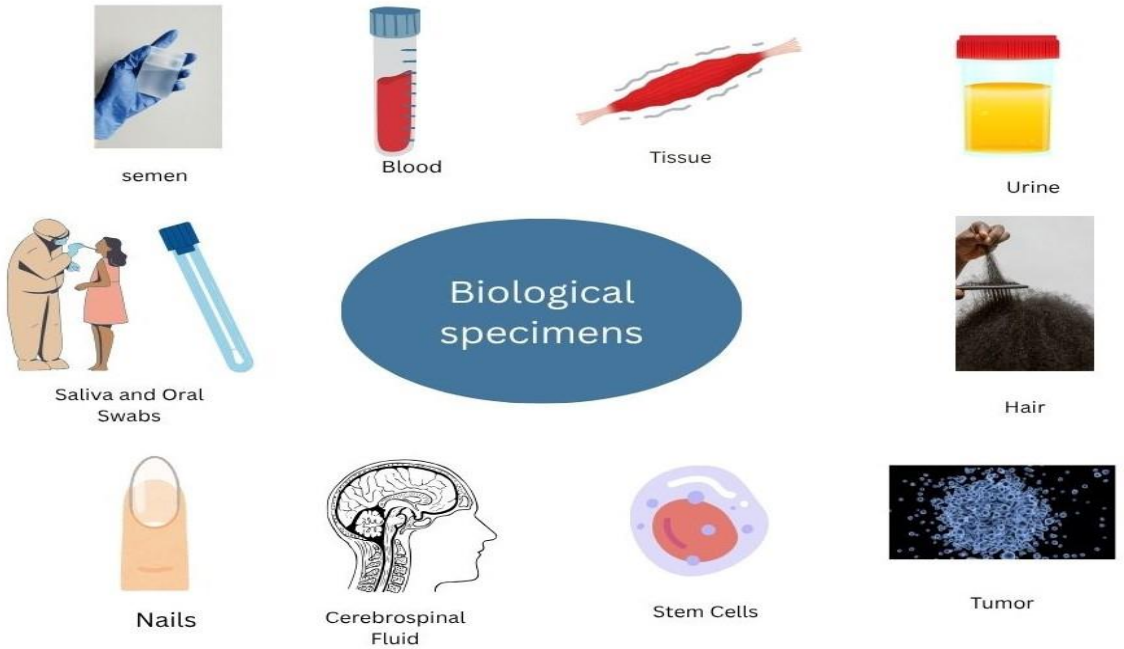

Figure 3. Widely used bio specimen types.

Biobanks can vary greatly in terms of size, research subjects, participant health, specimens obtained, sample collection, and processing and storage systems. Biobanks are categorised as Population-based biobanks. These biobanks offer samples from members of a broad population to investigate the roles that exposure to environmental variables and individual genetic vulnerability play in the development of conditions. Disease-oriented biobanks gather biospecimens that are unique to a given disease. A single tissue type may be the focus, while biospecimens from several sources relevant to a condition such as cancer may be included. Tissue biobanks, or tumor banks, collect and compare neoplastic and unaffected tissues to investigate the biology of a specific sample [7,8]. In general, the primary goal is to strengthen the awareness of the disease underlying foundationand/or identify novel, relevant biomarkers for a problem under investigation. For these efforts, intracellular particles like proteins, RNA, and DNA must be isolated. Biobanks are classified using four essential elements: the type of donor; the accumulating process and layout (size, scope, retrospective or prospective accrual); the biospecimens' characteristics (e.g., the most prevalent preservation category, such as frozen or just fixed); and the brand and target audience (e.g., one population, establishment, or different users). Biobanks can be found in healthcare institutions, research institutes, drug manufacturers, and patient advocacy groups. Research is the driving force of academic biobanks, which typically receive support from institutional and grant funding. Industry biobanks, however, are more focused on business and final outcomes [9].

3. Ethical and Legal Issues of Biobanks

Biobanks are special facilities situated between clinical and research facilities. As a result, as these innovative projects developed, numerous ethical and legal concerns surfaced. Although BBs are quite reminiscent of hospital pathology units, which also handle patient specimens, they confront more complex issues. These challenges are categorized as follows:

3.1. Ownership.

Since the utilization of human tissue samples for research and development (R&D), there has been a problem with donors' ownership claims. In addition to being used for strictly research purposes (such as determining biomarkers or analyzing cell biology), specimens can also be used to identify new drug targets or develop innovative treatments. In this situation, patients can become eager to benefit from the advantages and outcomes of commercialization. As of now, scientists are favored in court decisions. However, from the very beginning of a biobank, precise ownership rights or their deprivation should be defined. Furthermore, ownership issues are crucial for sample transfers between international researchers and for processes involving the use of specimens following the donor's death [10].

3.2. Consent limitation issues.

BBs' ability to function depends on optimizing consent. Both the patient's and the scientist's interests must be taken into consideration when giving consent. Because samples can be used only for a single study, traditional informed consent is insufficient for biobanking. Along with the variations in each nation's legal system, there is also no worldwide agreement on the consent question. It prevents samples from being shared internationally. General/broad consent is a new type of consent that was introduced. It consists of patients' consent to use their samples for current and upcoming studies without requiring direct patient interaction.

Nevertheless, all consents should be reissued if the framework changes [11]. In addition to the advancement of IT systems, a new solution for dynamic consent has been developed. Tools for convenient, ongoing communication with the patient are necessary for this kind of consent, as consent must be obtained for each new study. However, patients can be informed of significant findings, such as individual research results (IRR) and incidental findings (IF), to provide strong, informed consent. The definition of IF is "a finding concerning an individual research participant (or here, an individual contributor) that has potential health or reproductive importance and is discovered during conducting research but is beyond the aims of the study". The definition of IRR "is a finding concerning an individual contributor that has potential health or reproductive importance and is discovered in the course of research, when the finding is on the focal variables under study in meeting the stated aims of the research project". Parental (or legal guardian) approval is typically required for biobanks that store materials obtained from minors. The child's will must also be respected, including their consent and dissent [12]. Another query is that minors who had their parents' agreement to the acquisition and approval of their tissues as children need to give it again once they are of legal age.

3.3. Privacy preservation and anonymization.

Long-term preservation of biological samples requires appropriate anonymization and identification procedures. The most well-known laws require that a lot of information about the specific sample and its donor be obtained. Investigators and administrators are required by the EU Data Protection Directive to manage donor data in a competent and secure manner. In terms of their security, data anonymization that consists just of erasing identifying information is inadequate. Pseudonymization - the process of securing data by using a key or cipher in place of personal information is frequently used. As a result, sample coding is carried out consistently and in an orderly fashion for every sample. However, the greatest caution should be used when handling donor-identifying information linked to a database or coding symbol (number/barcode) that allows decoding. Researchers can contact the donor if they discover unintentional but important information about the donor's health [13].

3.4. Protecting and making the entire genome accessible.

The use of extensive and precise genomic sequencing raises additional concerns about the security of the data collected. Keeping one's entire genome sequence on file makes it more likely that others will try to use it for their own ends. In addition to being used as a means of identification, the genome sequence contains extensive information on the patient's health and load. As a result, every stage of sample processing incorporates rigorous security protocols. The number of volunteers declines because some donors are concerned about BBs having access to their genetic data. Nonetheless, the scientific community seeks to increase the usefulness of data by providing open access to genomic data while maintaining data anonymity and autonomy. To prevent misuse of such data while maintaining free access, new legislative measures are required, such as the Genetic Information Non-discrimination Act (GINA) [14].

4. Parameters Required for Building a Biobank

The complexity of managing and processing biospecimens makes establishing a biobank extremely difficult. The pursuit of official accreditation, financial viability, and adherence to standard operating procedures is an important marker for establishing a biobank.

To guarantee the integrity and caliber of biological specimens gathered, biobanks must adhere to strict professional standards. Strict adherence to accrediting procedures and best practices is necessary for this. Throughout the bio-banking process, it is imperative to prioritize fundamental components, including data security, informed consent, privacy protection, ethical governance, and procedural uniformity. According to the International Agency for Research on Cancer (IARC), establishing biobanks requires robust governance frameworks and a comprehensive approach to address ethical, legal, and social issues (ELSI). These recommendations are based on several worldwide initiatives, including the International Genomics Consortium (IGC), the European Committee for Standardization (Comité Européen de Normalisation, or CEN), and the International Organization for Standardization (ISO). Development of standardized guidelines has been greatly aided by the SPIDIA (Standardization and Improvement of Generic Preanalytical Tools and Procedures for In Vitro Diagnostics) project. IARC's suggested paradigm for the creation of biobanks is based on biospecimen type, quantity, aliquots, and size; containers for storage; storage conditions and temperature; regularity of biospecimen access; conditions for biospecimen identification; availability of space for storage; temperature monitoring requirements; related data; sustainability of operations and finances. The IARC document also provides useful material/data transfer agreement (MTA/DTA) templates and consent form, along with sample processing procedures [15]. For a biobank to be established, reliable, and sustainable, collection, preservation, and quality control (QC) processes must be standardized. Specific initiatives to standardize pre-analytical, analytical, and post-analytical processes in scientific labs, including biobanks, have been conducted in recent years. A biobank's data management systems, record-keeping procedures, and information technology (IT) infrastructure are essential elements. To preserve data integrity, safeguard participant anonymity, and enable dependable long-term biobanking operations, it is imperative to guarantee their resilience, effectiveness, and security. In fact, biobanks ought to be able to handle the process of erasing related data or destroying biological material beyond the scope of reconstruction. After a particular occurrence, a lasting legacy scheme needs to be made to outline who, what, when, where, why, and how biospecimens and related data will be relocated or deleted. From an ethical point of view, sample destruction following consent for use is typically not covered by informed consent, because biobanks inform participants about the samples' intended use to support biomedical research projects, suggesting that the material will be used in the future. Biobanks may include appropriate disclosures about the potential loss of specimens in their statements or consent agreements, as it is the only duty of a specific biobank to represent and safeguard the rights of those who have contributed samples. To prevent a shortage of biological samples after natural and manufactured disasters, biobanks should establish disaster recovery plans. The IARC publication offers comprehensive instructions for creating the recovery plan and outlines important steps to consider. These include prioritizing samples, using standard operating procedures (SOPs) to outline the activities to be taken, and establishing sufficient backup storage if samples must be relocated [16].

5. International Rules for Building Biobanks

Infrastructures in biobanking play a key role in facilitating interactions among biobanks, researchers, industries, and individuals by providing software, tools, and quality assurance services, as well as assistance with legal and ethical dilemmas. The following is a summary of the main global biobank infrastructures:

5.1. *International Society for Biological and Environmental Repositories (ISBER).*

It was founded in 1999 with the goals of standardizing biobanking procedures, fostering education and advancement, and facilitating networking. Creating criteria to ensure high-quality specimens for the next study is one of its primary goals [17].

5.2. *European, Middle Eastern, and African Society for Bio preservation and Biobanking (ESBB).*

It was established in 2010. Its goal is to promote and educate the biobank community in order to enhance the sharing of biospecimens. It encourages biobankers to work together, strengthening industry-academic biobank collaboration.

5.3. Pan European biobanking.

A roadmap for "a pan-European and broadly accessible network of existing and de novo biobanks and biomolecular resources" was suggested by the European Strategy Forum on Research Infrastructures (ESFRI) in 2006. The Biobanking and Biomolecular Resource Research Infrastructure (BBMRI) was suggested at that time. The European Commission funded BBMRI under the European Framework Programme from 2008 to 2011, and in 2013 it was formally granted the Community legal framework for a European Research Infrastructure Consortium (ERIC). The goal of BBMRI-ERIC is to make quality-controlled biospecimens and related data accessible for cross-biobanking studies. In addition to maintaining the list of European biobanks, BBMRI-ERIC assists biobanks with IT, ELSI, quality management, and the General Data Protection Regulations (GDPR) [18].

6. IT in Biobanking

Since the complete procedure for each material gathered in the biobank can be documented, IT systems are a crucial component of quality management. It offers a wealth of high-quality information, along with clinical data and consent forms pertaining to liquid and solid tissue biomaterials. Additionally, by documenting pertinent information (such as collection, processing, preservation duration, storage characteristics, material location within the repository, and ambient temperature), it facilitates the easy traceability of the biomaterial's trip. To maximize data in biobanking, using accepted terms based on international taxonomies is recommended, even if the majority of pathology findings provide detailed information about the cases [19]. The following criteria are included in the biobank document together with the participants' clinical, pathological, and other information, which includes Patient identity, demographic information, gender, date of birth, and vital sign status; Clinical stage and diagnostic information (cTNM); Details about the sample, including the date of sampling, quality of the sample, collecting technique, stabilization procedure, and preservation; Details about the lesion, tumor, size, pathological stage (pTNM), grade, histological type, and further crucial information unique to the illness condition; Sample data characteristics, including type, quantity, size, and pre-analytical data; Information about the concentration, purity, and integrity of DNA or RNA; and Details on the material's location within the storage facility, the type of storage utilized, and the surrounding temperature.

Applications for IT have been created to handle biobanking procedures and improve process effectiveness while maintaining consistency. This system can control Data

accessibility from the study group and manage data from molecular research. Software for biobank systems is built with security and resilience in mind. IT applications in tumor biobanks can be aided by a variety of software applications. These software applications allow for the recording of all processes and activities, comprising details about the administrator, the tools utilized, the chemicals and other necessities, and the time allotted. In a similar vein, sample collection, processing, acceptance forms, and anonymization can all be performed electronically to improve workflow quality management and productivity while reducing user error caused by manual data entry [20]. Most software programs enable monitoring of biospecimens' locations in biobank storage facilities and the procedures they undergo over time. Based on the total number of samples to be stored, these systems can optimize space use and suggest storage space for new material. A variety of information on the management and preservation of biomaterials can be recorded thanks to the software programs.

Along with the flow of processes, the ambiguous conditions that occurred during the procedure should also be included in this recorded information. Donation approval can also be tracked and managed with software. The shipment of tissue samples listed in the database, as well as procedures linked to the biospecimens, can be tracked using software applications. Additionally, information gathered from studies conducted using biobank resources can be entered into the biobank's computerized system, supporting ongoing growth of the information [21, 22].

7. Collection and Processing of Biospecimens

To diagnose the condition, the pathology laboratory gathers and analyzes every surgically removed specimen obtained from various surgical units. Thus, a key role in tissue biobanking is played by pathology labs and pathologists. A pathologist can perform a macroscopic examination of the specimen while taking appropriate tissue samples for biobanking and diagnosis. The pathologist's medical and scientific knowledge is crucial for the acquisition and storage of surgical excision materials, as well as for making diagnostic decisions. As a result, the pathologist plays a crucial role in maintaining continuity between research and medical care. Tissues, bodily secretions, and fluid samples are among the specimens gathered during clinical treatment. If at all possible, samples for study and diagnosis should be extracted from the same stage of the materials and gathered in different containers for biobanking [23]. A biobank must optimize the environment for sample survival and potential use while assessing all potential future applications. Both formalin-fixed paraffin-embedded (FFPE) tissues and frozen tissue (-80°C to -190°C) are recognized to have pros and cons in molecular research. Even though frozen tissue has less histological precision than cDNA microarray studies, genome amplification and sequencing, and DNA/RNA research, FFPE tissue and frozen biospecimens are ideal. Additionally, proteins in frozen tissue specimens are protected from enzymatic action and other forms of degradation, whereas their FFPE counterparts exhibit protein loss. Accurate pre-analytical data capture is essential for the molecular, proteomic, or immunoassay analysis of biospecimens composed of fluids and tissues.

7.1. Tissue samples.

Autopsy samples or surgical materials can be used to get human tissues. Avoiding both thermal and cold ischemia is crucial while delivering these tissues to the pathologist. To reduce

cellular-level alterations, the tissue sample container should ideally be stored on moistened ice cubes or refrigerated at 4°C until submerged in the fixing solution. It has been demonstrated that the ischemic process alters the values of biomarkers detected by conventional immunohistochemical or molecular methods. The type and length of fixation, as well as the storage conditions and duration, must be specified in order to fix solid tissue samples [24]. Variables including tissue ratio, fixative volume, fixation duration, temperature, and tissue thickness all affect how well biospecimens are fixed. Nucleic acid fragmentation occurs when biospecimens are fixed in formalin. It is advised that biopsy specimens be fixed for 6–18 hours and surgical samples for 12–36 hours, as the duration of fixation also influences the purity of the nucleic acid. In contrast to formalin fixation, using 70% ethanol or alcohol may yield nucleic acids of higher quality and may be more appropriate for molecular research. It has recently been shown that tissue samples treated with the commonly recommended tissue preservative RNA Later produce superior-quality RNA and gene expression profiles than samples that are snap-frozen or FFPE [25].

7.2. Liquid biospecimens.

These include lipids, proteins, cells, and metabolites that have the potential to function as biomarkers. These include ascites, tear fluid, seminal fluid, bronchoalveolar lavage, urine, plasma, serum, and whole blood. Among the pre-analytical details needed for fluid substances are the principal collection tube types, the temperature and waiting period before centrifugation, the centrifugation parameters, and the temperature and length of long-term storage. The container for obtaining a sample of blood is a crucial pre-analytical element. The Stabilizers for nucleic acids or blood thinners that these tubes, as well as their contents, may contain may impact the blood sample's biomarker analysis. Proteins, hormones, and other indicators used in a variety of analytical procedures have been shown to be affected by the tube content. Furthermore, recent research examining the waiting period before centrifugation has shown that it may affect blood sample protein levels. Another element influencing protein stability is the storage temperature of the sample [26, 27]. When the samples were kept at room temperature for more than 4 hours or at 4°C for 24 hours, there was a discernible loss of protein. White blood cells, red blood cells, plasma, and serum are among the several fractions found in blood, which is one of the most commonly utilized biomaterials. Blood should only be collected in tubes that are compatible with the test being performed. For tests involving serum, an assortment tube containing a silicon or thrombin-like coagulation booster is required. For studies based on DNA or RNA, anticoagulated blood is recommended. Anticoagulants come in a variety of forms, but Citrate-stabilized plasma samples provide superior-quality RNA and DNA compared to those stabilized with other anticoagulants. Collection tubes coated with EDTA work well for a variety of DNA and protein-based tests, they are insufficient for cytogenetic research. It is possible to separate the obtained blood samples into fractions. Proteins, lipids, tiny molecules, and nucleic acids can all be analyzed using serum and plasma [28]. Cell concentrates can be used as a source of cellular nucleic acids or for flow cytometry and functional research. Blood components can remain viable at ambient temperature for up to 48 hours. There should be as little time as possible between sample collections and processing (ideally less than 24 hours). One significant advancement that has just been made for cancer victims' genetic profiling is the liquid biopsy technique. DNA not found in cells (cfDNA) extracted from trace amounts of patient blood contains a variety of biomarkers that indicate tumor-specific alterations. Therefore, this approach is helpful for detecting resistance and

recurrence as well as molecular monitoring of cancer treatment. The initial "liquid biopsy" test with EGFR mutations in individuals with non-small cell lung cancer (NSCLC) was just approved by the FDA. Figure 4 shows the workflow concept for sample distribution, storage, and collection in biobanking [29, 30].

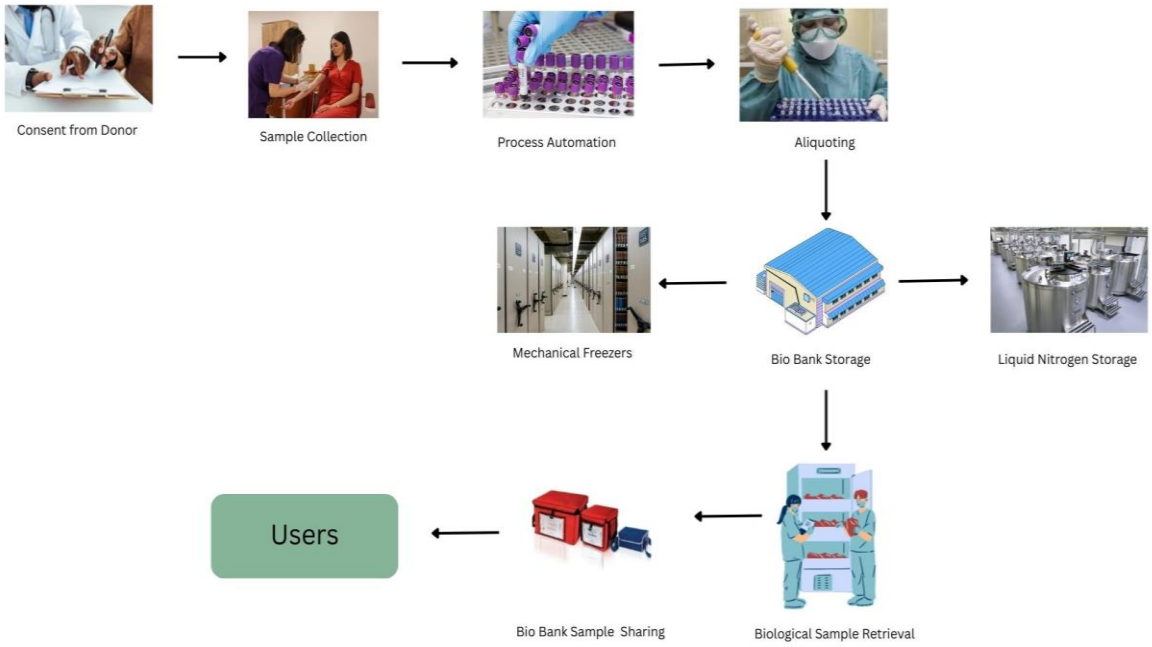

Figure 4. Sample distribution, storage, and collection in biobanking.

8. Storage of Biospecimens

Storage facilities have a significant role in preserving the quality of samples. The creation of a storage facility is influenced by the type of biobank to be constructed, the specimens to be archived, the duration of sample preservation, the samples' intended use, and available funding. A biobank storage facility requires more advanced, complex conditions and more costly equipment than the simple conditions needed to store FFPE blocks in areas with air conditioning and temperatures below -25°C. Therefore, a variety of temperatures can cause biospecimens to freeze depending on the sample's water content and other tissue constituents. Degradative chemicals influenced by temperature are present in all biological specimens. The biospecimens' protein activity declines with a drop in the ambient storage temperature. Therefore, the ideal temperature for storage should be lower than the temperature at which proteins become inactive. Pure water's glass transition temperature (Tg) is -132°C, and below this temperature is the ideal storage temperature. Below this temperature, the majority of the physical and chemical reactions that deteriorate the item slow down. Specimens can be kept at low temperatures by employing liquid nitrogen-based (LN_2) cryogenic storage or mechanical freezers. In locations with unstable power supplies, LN_2-based storage units are chosen over mechanical freezers because they offer efficient and long-term storage. Huge storage units and smaller aluminum dewars are the two main types of LN2-based storage units.[31]. Both are vacuum-insulated, double-walled storage rooms that effectively contain LN_2. The specimen capacity and sizes of the units vary. Aluminum dewars are easily accessible, compact, and portable containers that can be set up in laboratories. Although they offer low LN_2 use and a steady storage temperature, the majority of them need the LN_2 to be manually filled in order to keep the temperature stable. Usually, dewars don't have options for LN_2 level control or complete monitoring. The medium-sized to huge storage spaces offer prolonged preservation

of specimens, which are known as liquid storage units. Because of their size, they may need a specific space or be set up in a laboratory. With a monitoring system, most of these machines can automatically enter the LN_2 level and temperature. Liquid nitrogen can be used to store biospecimens in either the liquid or vapor phase. The vapor (gaseous) phase surrounds the biospecimens in containers during the combustion phase, storing them in nitrogen above the liquid phase. In addition to providing suitably low temperatures below the glass transition temperature Tg (-132°C), Biospecimens are protected when stored in the LN_2 vapor phase (≤150°C) from the dangers of contamination and liquid phase storage-related safety issues. Because of this, vapor phase LN2 storage is usually preferred over liquid phase LN2 (-196°C). But it's important to keep in mind that LN_2 maintains a steady temperature of -196°C. When using LN_2 freezers, oxygen level sensors need to be used and calibrated. Gloves and protective goggles must be worn. A standard operating procedure concerning safety and health hazards measures should also include appropriate training. Another crucial part of the storage unit is the container system. Cryogenic straws, bags, and screw-cap vials are the three primary kinds of containers. Screw cap vials, which come in volumes ranging from 0.2 to 5 mL and are made of polystyrene and polypropylene, are advised for low-temperature long-term storage. It's critical to use a membrane to cover vials in order to minimize poisoning of nitrogen in the liquid. Often used in blood banking, cell-freezing bags can also be used to freeze other tissues. It is common knowledge that brain slices can be stored in these bags. For sample amounts under 5 mL, vial systems are advised, and for greater volumes, bags. Cryogenic straws are made to store specimens in liquid nitrogen safely and are hermetically sealed. These straws exhibit physical properties that enable them to withstand extremely low temperatures and high retention pressures because they are composed of biocompatible, chemically inert materials. They remain stable under extreme conditions, such as multiple freeze-thaw cycles, prolonged exposure to low temperatures (years), or snap-freezing. Another way to reduce tissue desiccation is to wrap Slices of frozen tissue in aluminum foil [32]. Sample size, necessary rates of both warming and cooling, possible environmental or sample contamination, parameters and temperatures during storage, accessible area for storage, frequency of access, specimen identification needs, processing and preparation of the specimen methods, and financial conditions are the factors to take into account when choosing storage containers for biospecimens. The typical tools utilized in biobanking are:

8.1. Mechanical freezers.

Different electrical voltages, sizes, and combinations are available for mechanical freezers. Since these devices are connected to power systems, it is necessary to have both an emergency response plan and a backup power plan. The primary benefits of mechanical freezers are a lower initial investment cost and simpler sample access. Using -20°C is rapidly declining as tissues disintegrate, even though biospecimens can be stored at -20°C temperatures lasting at extremely low temperatures (-150°C and -80°C) over a longer period of a longer amount of time. The majority of facilities favor using extremely low temperatures since temperatures near -70°C might cause ice crystals to grow inside the biospecimens. Cascade compressors require constant electrical power to remain warm, even though they can reach temperatures as low as -140°C. Variables that affect freezer temperature stability include ambient temperature, humidity, open doors during sample loading, and freezing within the refrigeration unit [33]. As a result, freezing units must be kept in areas with adequate air conditioning, and any ice must be cleared regularly.

8.2. Refrigerators.

These are now utilized when storing materials below room temperature preserves their durability. Before becoming ready for extremely low-temperature storage, 4°C storage could serve as a transitional phase. Similar to mechanical freezers, refrigerators need a backup power plan and temperature stability [34].

8.3. Ambient temperature storage.

In standard pathology lab procedures, it is possible to store FFPE specimens in ambient temperatures. Biological components can be stored for long periods at ambient temperatures thanks to newly developed biological storage matrices. These matrices allow the preservation of a wide range of tissue specimens, including FF, PAX gene-fixed, paraffin-embedded, ethanol-fixed, and lyophilized samples. They can be useful when mechanical or cryogenic equipment is not available for practical or financial reasons. After brain dissection, tissue was stored for 15 years at -70°C. DNA viability is preserved at extended storage around -80°C, usually in contrast to the contradictory findings for RNA [35]. In a similar vein, tissue maintained at or below -70°C may preserve the proteome for years. The stimulation of the epidermal growth factor receptor in breast cancer excision materials was investigated in another study, and the results were unaffected by storage temperature. For long-term storage, an optimal temperature of -80°C has been proposed as the ideal. Even while storing these pricey freezers may lessen the impact of temperature above -150°C changes caused by simply opening the doors, more research is necessary before recommending them. In order to preserve biomolecule output and avoid degradation, blood specimens need to be treated as soon as possible. It was shown that blood samples maintained at ambient temperature for an average of one month, 4°C, and -20°C can give tolerable yields and quality for DNA extraction. The amount of extracted DNA will decrease as the storage period lengthens because the erythrocytes and certain leukocytes may lyse. It has been advised in these situations to freeze the samples of blood at -80°C to avoid lysis and boost the amount of DNA. Extracted DNA can remain stable for weeks at 4°C, months at -20°C, and years at -80°C. However, temperatures over -80°C cause RNA lability and destruction to start [36].

8.4. Freeze-thaw cycle.

Cycles of freeze-thaw can damage cells and biomolecules designed for research. The destruction of cells accelerates with cycles being repeated through necrosis and apoptosis. Aliquoting the samples to the correct size is essential for reducing the frequency of prior use and successive freeze-thaw cycles. If aliquoting isn't done, specimens should be kept on either dry or moist ice throughout the sampling procedure to maintain sample viability. As often, specimen consistency can be preserved under Tg (-132°C), which is the temperature at which cell metabolism is almost completely stopped [37]. Thus, every time a specimen is heated over Tg, a micro-thaw event takes place. Temperature swings can be caused by a variety of factors, including frequent door openings, mechanical failures in the freezer, and power outages. Since RNA is the most susceptible biomolecule in unresolved tissues, most research on freeze-thaw cycles focuses on its integrity. Several investigations have demonstrated that, especially in autopsy brain tissue, repeated freeze-thaw cycles are adequate to lower RNA quality. Similar to frozen tissue samples, blood samples should undergo as few freeze-thaw cycles as possible. This can be accomplished by both aliquoting and pre-extraction of stable molecules (DNA).

Lastly, the biospecimens must be aliquoted and documented with extra caution. To shield biospecimens taken from the same patient from the negative effects of unfavorable circumstances, like a power outage, they should be separated and then stored in two distinct repositories. In the event of failure, conditions for preventive measures ought to be established. The methods used for tissue preservation and storage are shown in Table 1 [38].

Table 1. Storage conditions for tissues in biobanks.

Tissue	Target biospecimen	Methods of preservation (such as medium, buffer, vial type, or kit)	Conditions of storage
Blood	genetic material DNA	serum or whole blood, EDTA	Stored for years at -80°C
	RNA, or messenger	Pax gene®	Stored for years at -80°C
	Proteomics	Heparin-containing tubes for separating plasma and serum, as well as a plain tube	Plasma and RBCs stored under -80°C
	Biochemistry	Heparin-containing tubes for separating plasma and serum, as well as a plain tube	Instantaneous analysis of plasma or years at -80°C
	PBMC (Peripheral Blood Mononuclear Cells)	BD CPT™, LeukoSep™, acid citrate dextrose	LN2 with a Cryo preservative or -80°C is preferable.
	Tumour Cells	BCT® tube	LN2 or -80°C with a Cryopreservative is preferable.
	Cell-free DNA	Streck®	−80°C for years or immediate extraction
	Non-coding RNA	a tube for plasma separation or plasma	For stability, Plasma specimens need to be immediately stored for up to a year at -80°C
	Exosomes	Plasma or a tube for plasma separation	-80°C for years
	Platelets	EDTA	Use a series of centrifugations to acquire the platelet-rich plasma, and finish the process in 48 hours
	Metabolomic	Heparin-containing tubes for separating plasma and serum, as well as a plain tube	−80 °C for years
	Buffy coat	EDTA	For the stability of RNA, store at -150°C.
	Red blood cells	EDTA	Should be aliquoted and kept at -80°C
	Plasma	Lithium heparin/EDTA	Stored at -80°C
	Serum	No anticoagulant	Preserved at - 80°C.
Tumor	DNA	Snap-freeze tumor components in chilled isopentane	−80°C or liquid nitrogen
	RNA	RNA later™-RNA conservation	Remove the preservation medium and keep it at -80°C
	Protein	In cooled isopentane, the tumor portion snap freezes.	store at −80°C
	Microscopic morphology	FFPE–Optimal Cutting Temperature medium (10% buffered formalin) -frozen embedded snap	RT for years in arid conditions, years at -80°C
	Cultured cancer cells	Culture media containing or lacking fetal bovine serum (FBS) prior to cell isolation	LN2 in immunocompromised mice with a Cryopreservative or implant
Cervical cytology	Protein, DNA, RNA, cells	Thinprep (TP) liquid biopsies with 20 cc of PreservCyte	−25°C
Urine	Protein, Metabolic products, DNA, RNA	9 ml in the Vacutainer system	Either immediate analysis or direct storage at -80°C
Semen	Protein, Semen analysis, DNA, RNA	A container that is sterile	LN2 with a Cryopreservative or -80°C is preferable.
Stool	Microbiome, DNA, RNA, Proteome,	Genetec tubes or a sterile container for DNA analysis	Either quick extraction or direct storage at -80°C
Saliva	Biomarkers, DNA	A collecting kit or sterile container	−80°C for years
Breast milk	Analysis of the biochemical composition and the presence of organic pollutants (POP)	sterile, spotless bottles, such as those coated in Teflon	At -20°C over prolonged periods of time. Human milk can be safely frozen for a minimum of three months
Nail and hair	Exposure to brominated and organophosphate flame retardants, metal traces, DNA, and the consequences of cosmetics	After many weeks following a recent nail trim, the nails should be trimmed. A neatly labeled envelope	Similar to short-term storage, long-term frozen storage at -20°C is possible

9. Umbilical Cord Blood (UCB) in Biobanking

Human tissues, skeletal muscles, bone marrow, blood, and embryos are all sources of stem cells. Through division and the production of comparable daughter cells, stem cells regenerate themselves. Stem cells are resistant to differentiating into particular progeny cells. Asymmetrical division of stem cells results in the production of one stem and one non-stem cell; the daughter stem cell regains its "stemness" qualities while the daughter non-stem cell may differentiate into a more specialized one [39]. "Pluripotent" stem cells differentiate into tissues like ectoderm, endoderm, and mesoderm that are generated from germinal layers. Embryonic tissue is an appropriate example of mesenchymal stem cells that originate from the inner cell mass. The three most prevalent varieties of stem cells are UCB, mature, and embryonic. Though historically viewed as an undesirable byproduct of childbirth, these stem cells are among the best-recognized sources of hematopoietic progenitor cells/hematopoietic stem cells (HPCs/HSCs), on par with those found in bone marrow and peripheral blood. Dr. Pablo Rubinstein founded the first CB bank in 1991, after the first UBC transplant was performed in 1988 [40].

10. Applications of UCB

The FDA has approved the use of UC units' proliferative stem cells to treat about 80 different illnesses. In addition to hereditary immunological and metabolic problems, these include myelodysplastic syndromes, acute and chronic leukemia, lymphomas, and solid malignancies in children, as well as non-cancerous hematological disorders such as thalassemia, aplastic anemia, and sickle cell anemia [41]. More recently, UC-derived MSCs have been investigated for a number of conditions, including wound healing, infectious diseases, neurological, musculoskeletal, metabolic, and developmental abnormalities. The usage of UC-MSCs has been shown to improve the left ventricular ejection fraction in cardiovascular diseases. Furthermore, when UC-MSCs are administered for myocardial infarction, the infarct's size is significantly reduced, and LVEF is increased. Patients with spinal cord injuries have reported enhancements in bowel and bladder control, neurological, motor, and sensory capacities after intrathecal and/or intravenous injection of UC-MSCs. Neurological diseases such as amyotrophic lateral sclerosis (ALS), Huntington's disease (HD), Alzheimer's disease (AD), and Parkinson's disease (PD) may also benefit from stem cell treatment. The prospect for osteogenic as well as chondrogenic differentiation is strong in UC-MSCs. In ovariectomized as well as osteoporotic patients, UC-MSCs improve bone growth metrics and encourage bone regrowth. MSCs from UC improve cartilage regeneration. MSCs generated from UC have also been studied for their potential to modulate GvHD. After receiving an HLA-haploidentical stem cell transplant, UC-MSCs demonstrated a preventive effect against GvHD [42, 43]. A lower frequency of chronic GvHD was linked to UC-MSC infusions as well as a decrease in T helper 2 (TH2) and natural killer (NK) cells, which cause the fibroproliferative alterations that follow GvHD. MSCs produced from UC may also be used to treat diabetes. In type 2 diabetes (T2D), UC-MSCs have been linked to decreased dosages of hypoglycemic medications, controlled glycemia, and enhanced pancreatic islet function. Type 1 diabetes (T1D) can also be cured by using UC-MSCs as a cell therapy and developing into insulin-producing cells (IPC). UC-MSCs have also been used to treat patients with severe COVID-19 infections since the latest epidemic began. Across several trials (ChiCTR2000031494) (NCT04339660)/ (ChiCTR2000029990) (IRCT20200217046526N2)

(NCT04355728), UC-MSC transfusion improved lymphocyte counts, survival rates, and recovery times while also significantly lowering inflammatory cytokines. Finally, it has been noted that UC-MSCs have the ability to heal wounds and promote effective skin regeneration in burns and chronic diabetic ulcers, respectively. Utilizing UCB stem cells for a range of diseases is depicted in Figure 5 [44].

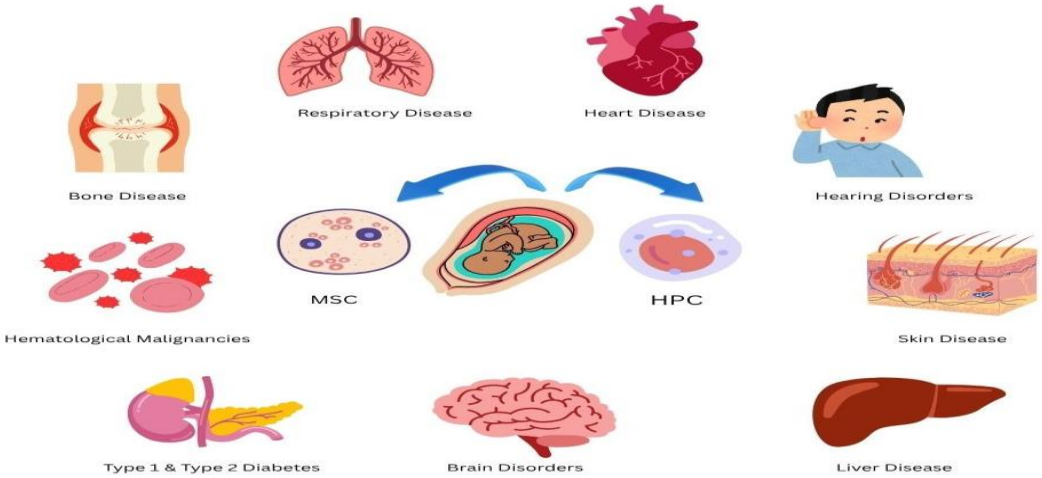

Figure 5. Use of UCB stem cells for various diseases.

11. Collection of UCB

Due to the abundance of embryonic stem cell sources in UCB, these cells are frequently used to treat immunological diseases and genetic conditions, including blood cancers. Doctors must get donors' informed consent before drawing blood from the umbilical cord. Mothers need to be examined for invasive biological diseases, including hepatitis B virus and hepatitis C, as well as HIV reactivity. Furthermore, bioMérieux (Hazelwood, MO) is used to test blood for sterility. The cord's blood is typically drawn as soon as the baby is born, but before the placenta is expelled. The placenta should be in close proximity to the first clamp, while the baby's umbilicus should be at least 5 cm distant from the second clamp [45]. To guarantee sterility, the UC is covered with spirit or betadine before blood is drawn. There are two methods for collecting UCB: syringes and bags. With the cartridge system, USB is often collected using syringes of different sizes, including a 200 mL tiny bag and a 60 cc large syringe. Expert blood collectors typically use a syringe to draw blood while maintaining a high level of cleanliness. Before the placenta is removed, these collectors' blood-gathering procedures could take up to five minutes. In addition, this process is easy, painless, and non-invasive. Following a straightforward venipuncture, the sterile vessel is used to collect the blood. However, during this straightforward process, there is a significant risk of UCB contamination. As a result, when drawing umbilical cord blood, sterile procedures must be followed. Since blood samples are taken after the cord is clamped, there is typically little risk to the mother or the infant during the procedure [46, 47]. For both vaginal and C-section deliveries, it is safe to obtain cord blood or tissue. The majority of collectors use bag collection because they believe it is simpler than syringe collection, which takes 2 minutes. However, sterile kits are pre-anticoagulated for both kinds of blood collection [48]. They must come with all the equipment required for shipment, including a container that can withstand crushing and a double-layered restraint. The ideal pH, carbon dioxide, and oxygen levels must also be present in these kits. Since this may significantly impact cell viability, it is essential to maintain ideal temperature control and shipment prior to analysis. Various temperature ranges for the preservation and transport of

UCB, including 4°C, 4 -7°C, 4-10°C, and 4-24°C. As required by regulation, the mother must have blood drawn using the supplied vacutainers for infectious disease marker (IDM) testing prior to UCB collection. Within 28 to 34 hours, the umbilical blood must be brought to the laboratory. Under careful, documented circumstances, the shipping procedure to labs can be completed successfully. Many UCBs should ideally be processed in part by automation. Prior to cryopreservation, UCB mostly depletes its red blood cells (RBCs). Given that RBCs make up over 50% of blood donations, this process guarantees a higher number of stem cell retrievals because most stem cells are found in a fraction of mononuclear cells (MNCs), which is solely needed to operate banking [49,50]. Volume reduction also helps UCB banks reduce storage space, enabling lower amounts of Cellular products such as dimethyl sulfoxide (DMSO). Gelatin sedimentation and density gradient separation are two techniques used to boost stem cell survivability. After being gathered in the kit, the UCB needs to be cushioned and insulated to control the temperature. The UCB bags' exterior surfaces need to be cleaned with an alcohol-based solution prior to entering the main laboratory. Mononuclear cells are added to a pre-cryopreserved cell deferment under rigorous aseptic conditions following RBC aggregation with hydroxyethyl starch and agitation. Variability of cell, the assessment of CD45+ and CD34+ cells, and the estimated total nucleated cells (TNCs) are frequently used to determine the quality of cryopreserved UCB [51].

12. Cryopreservation of UCB

The wet stage typically occurs throughout the period of ice formation during cryopreservation, which uses extremely low temperatures to protect tissues' and cells' structural and functional integrity. Cells and tissues can be maintained in a stable state after freezing because the optimal low sub-zero range is usually at or near liquid nitrogen's temperature (-196°C). For cells to survive and retain their structural integrity, cryopreservative chemicals are required [52]. An alternate method is verification, which, unlike cryopreservation, solidifies the liquid state, preventing ice from crystallizing or growing. A cell freezer that is controlled by an automated microprocessor is used to cryopreserve umbilical cord blood. The autologous plasma is gradually mixed with a comparable amount of dimethyl sulfoxide (DMSO) over a period of 20 minutes. The cryopreservation protocol calls for a regulated rate freezing procedure to progressively reduce the temperature to -80°C. In cryopreservation, autologous plasma is essential for shielding cells from animal and non-self-proteins. Proper freezer temperature protocols must be followed to comply with regulatory standards, keeping each frozen sample's cryopreservation run under control and recorded [53]. Similarly, to preserve the viability and likelihood of the cell artifact, the UCB is stored and processed using nitrogen in the liquid or vapor phase. The two types of frozen tissue products used in UCB banking are technically plasma depletion (PD) and red cell reduction (RCR). The PD techniques freeze all the cells in 10% dimethyl sulfoxide (DMSO) after removing the plasma cells. In the RCR procedure, 21 mL of UCB, mostly WBC, is separated by centrifuging the UCB in albumin solution. After adding four millilitres above 50% DMSO, 25 milliliters of frozen cellular suspension are produced. UCB approaches have been more expensive for the bank and more challenging to thaw, despite being less expensive to process. UCB units are utilized to treat disorders like thalassemia, despite the fact that they are properly cleaned. However, blood cells can be harmed by more than 1% DMSO for more than 30 minutes at 37°C [54]. To lessen negative effects on transplant recipients, DMSO must be eliminated after defrosting. The UCBs can be stored in.

12.1. Public cord blood banking.

Donated UCBs are processed and stored by public cord blood banks that are supported and funded locally or nationally. The donated UCBs have been HLA-typed and added to a national or international registry, enabling transplant centers worldwide in need of donors to find them, much as bone marrow registries do. Any patient in need of a transplant who is a suitable match for a CBU can obtain one from a public bank; the donor family is not the only recipient. Donors or their family members may not always have access to their designated donor unit in the future when dealing with public banks [55]. Although processing and storage fees for the donated UCB are not borne directly by the family, a UCB acquired from a public bank outside Canada can be very expensive. However, the public bears the heavy burden of starting and maintaining a national public bank [56].

12.2. Private cord blood banking.

In private cord blood banks, processed UCB units are preserved, sometimes referred to as family cord blood banks, for the family's personal use. The mother is usually designated as the legal caretaker of the banked CBU, and the newborn child's family pays a fee to process and store the CBU. As a result, only the family that deposited the CBU can access it, and they can do so when needed. The family is charged by private banks to handle and store the CBU for their sole use [57].

13. Challenges of UCB Biobanking and its Derived Stem Cell Therapies

Even though UCB biobanking has significant promise for UC-derived stem cell treatments, there are still several restrictions and challenges. First, there is still a chance of microbial contamination when CB and tissue are being purchased. This is because birth surroundings are by their very nature non-sterile. Longer transit and incubation intervals between collection and handling may pose a danger, even worse, jeopardizing the safety of UC samples, their potential cellular makeup, and, thus, their quality [58]. Furthermore, although UC tissue is frequently treated with antibiotics before transport to reduce the risk of contamination, some antibiotics can trigger adverse reactions, further complicating the assurance of biological security and obtaining regulatory agency approvals. Regarding the possible hazards associated with stem cell treatments, the US Food and Drug Administration has also highlighted other safety issues. These include the risk that stem cells may undergo malignant transformation, leading to tumor formation, or differentiate into undesirable cell types. Additionally, applying specific techniques to evaluate the safety and functionality of stem cell therapy for medical use is expensive and resource-intensive [59]. This financial burden, along with the cost of tissue cultivation, further hamper the research and development of UC-derived stem cell therapeutics. It should be noted that cryoprotectants, primarily DMSO, are frequently used in MSC cryopreservation procedures [60].

14. Conclusion

A growing number of research projects are either creating new biobanks or using stored biospecimens, demonstrating the growing global significance of biobanking. By allowing researchers to do extensive, high-resolution studies, these repositories improve patient care and scientific knowledge. Donors gain from cost-effective processing and well-established

operating standards, as well as access to predictive genetic data and preventative healthcare recommendations. Through the exchange of best practices and advice for new establishments, international networks and cooperative organizations are essential in forming the infrastructure of biobanks. This underscores the importance of legislative and regulatory frameworks being ready for biobanking's future growth. Biobanking is a multidisciplinary field that offers numerous prospects for innovation by bridging clinical care, industry, and scientific research. The variety and accessibility of biospecimens and bioimages, cost control, patient and public involvement, and strong national and international governance are important elements that will shape biobanking's future. To facilitate significant research, a healthy biobank needs to provide high-quality, reasonably priced specimens. In instance, umbilical cord (UC) biobanking has grown significantly. Low cell yields, inconsistent sample quality, and restricted access are still issues, though. Optimizing cryopreservation, standardizing volume reduction techniques, and harmonizing quality control, regulatory compliance, and ethical measures to protect donor rights are all necessary to address these problems. The implementation of AI in biobanks is still in its infancy, but it holds the promise of progressively integrating into various aspects of biobanking. AI-based systems, which include machine learning and/or natural language processing methods, can be designed to understand and explain the contents of consent forms and to manage web-based communications with biobank participants. If a participant were to withdraw, an AI system could destroy any associated data and notify the biobank's administrators to dispose of the corresponding biological specimen. Moreover, if an AI system were linked to an automated sample storage system, it could relocate bio-samples to utilize vacant spaces within the storage system more efficiently. AI may also be used to develop standard operating procedures (SOPs) tailored to specific bio- sample uses, as well as to identify or match a biospecimen to a specific study appropriately. Additionally, AI can also institute a biospecimen collection plan for prospective biomedical research based on its analysis of the biobank's distribution and inventory status, as well as research trends. DL algorithms, such as neural network-based models for image data, are being adopted for automatic classification and early detection of severe diseases, such as cancers and neurodegenerative disorders. MRI image data can be used to classify dementia disorders (such as Alzheimer's disease) using AI technologies and frameworks. AI is also being applied to analyze biomedical samples and predict risk factors for chronic diseases such as diabetes, obesity, and cancer. AI tools are used to handle the larger amount of data that is generated every day, to provide better healthcare. Biobanks are playing an important role in transforming personalized care by coupling biological data with electronic health records (EHRs). AI may also be utilized to aid in the quality assessment of UC-MSCs, which is especially important given their significant heterogeneity, and to streamline the biobanking and cell therapy processes. AI is not widely adopted yet in biobanking, and its definite potential remains to be fully established. Investigating and further validating appropriate AI algorithms in relation to biobanking, more specifically, is essential to expand the applicability of AI into the field. The development and long-term viability of biobanks depend heavily on harmonization. Numerous initiatives have been made in the USA and Europe to establish cooperative dialogue platforms for the creation and implementation of common protocols and guidelines that primarily address the acquisition of samples, their collection and storage, treatment data pertaining to the samples, the exchange of materials and information, and the administrative and financial management of the infrastructures linked to biobanks. Alongside the technical harmonization of biobanks, it is also vital to harmonize their ethical and regulatory aspects, including

participant consent, data confidentiality, sample anonymization, and results return. A more organized, multicenter collection of data and samples, homogeneous patient groups with extensive, well-described case histories, and the potential to conduct research on sizable patient cohorts and subcohorts are just a few of the significant outcomes that can result from improved harmonization. By leveraging creative and standardized logistics management and sample traceability systems, universal standards could also ensure greater long-term safety in sample management, storage, and distribution. The new challenges presented by biomedical research cannot be met by a disjointed set of protocols and guidelines; instead, we need similar research platforms that yield repeatable results and, most importantly, a shared effort to analyze numerous samples in various infrastructures, making research findings more applicable and efficient in day-to-day clinical practice.

Authors Contributions

Conceptualization, V.R.K.; methodology, V.R.K.; investigation, H.K.; data curation, H.K.; formal analysis, H.K.; writing—original draft preparation, H.K.; writing—review, editing, supervision, L.P.N. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

There are no conflicts of interest.

Abbreviations

Abbreviation	Definition
BB	Bio Banks
BBMRI	Biobanking and Biomolecular Resource Research Infrastructure
CEN	European Committee for Standardization
DTA	Data Transfer Agreement
ELSI	Ethical, Legal, and Social Issues

Abbreviation	Definition
ERIC	European Research Infrastructure Consortium
ESBB	European, Middle Eastern, and African Society for Bio Preservation and Biobanking
ESFRI	European Strategy Forum on Research Infrastructure
FFPE	Formalin Fixed Paraffin-Embedded
GDPR	General Data Protection Regulations
GINA	Genetic Information Non-discrimination Act
HSC	Hematopoietic Stem Cells
IARC	International Agency for Research on Cancer
IF	Incidental Findings
IGC	International Genomics Consortium
IRR	Individual Research Results
ISBER	International Society for Biological and Environmental Repositories
IT	Information Technology
MSC	Mesenchymal Stem Cells
UCB	Umbilical Cord Blood

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