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Menstrual Blood Stem Cell Banking: Current Knowledge, Clinical Applications, and Future Prospects

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Abstract

Menstrual blood-derived stem cells (MenSCs) are a new, non-invasive, and ethically sound source of mesenchymal stem cells that hold great promise for regenerative applications. This paper discusses the existing state of research on MenSCs, focusing on their biology, harvest, isolation, and preservation via menstrual blood banking. MenSCs have a high proliferation rate, multipotency and immunomodulation, and can differentiate into diverse cell lineages, including neural, cardiac and osteogenic. Their ability to be obtained via regular menstrual cycles presents a renewable and accessible source of stem cells. The paper discusses the progress in freezing techniques and the development of menstrual blood banks. It also discusses the broad spectrum of clinical applications for MenSCs in regenerative medicine, central nervous system injuries, heart diseases, infertility, as well as metabolic and autoimmune diseases. Although standardization and awareness are needed, there is potential for MenSC banking in future applications of personalized and regenerative therapies.

Keywords; Menstrual Blood Stem Cells (MenSCs), Stem Cell Banking, Regenerative Medicine, Cryopreservation, Clinical Applications.

INTRODUCTION

The scientific world has experienced an unprecedented increase in interest in the various applications of stem cells obtained from menstrual blood in recent years, leading to extensive research into the viability of menstrual stem cell banking. These stem cells, sometimes referred to as "menstrual blood-derived stem cells (MenSCs)", have demonstrated a variety of qualities that could transform medical treatments in a number of different fields [1]. MenSCs are a new source of mesenchymal stem cells (MSCs) that have shown promise in differentiating into a variety of cell types. This opens up possibilities for regenerative therapies that can repair tissue and possibly treat diseases that were previously incurable [2]. MenSCs are more appealing than traditional sources of stem cells because of their accessibility, which is made possible by a non-invasive method of collection, and the repeated possibilities for collection during menstrual cycles. Its therapeutic potential for applications in regenerative medicine, such as skin healing and dermatological diseases, supports this trend [3], [4].

The need of creative methods for handling and using menstrual by-products is highlighted by the changing global attitude on menstrual health. In addition to being in line with these changing attitudes, menstrual blood banking offers a reliable and morally sound source of biological material for innovative medicinal therapies. The future of menstrual blood banking seems hopeful as research into MenSCs' capabilities and applications advances, ushering in a new era of regenerative and customized medicine [5]. For the foreseeable future, research and investment in this emerging sector will be extremely exciting since it has the potential to revolutionize methods to tissue regeneration and disease treatment.

Because of their special qualities, MenSCs are an important resource for regenerative medicine. They have benefits like minimal immunogenicity, high proliferation rates, pluripotency, and non-invasive collection techniques [6]. Numerous studies have described MenSCs, highlighting their negative expression of hematopoietic stem cell markers and detecting a variety of surface chemicals suggestive of MSCs. MenSCs and bone marrow-derived MSCs have similar phenotypes, such as surface marker expression, spindle-shaped morphology, and conventional three-line differentiation. They can be used in a variety of therapeutic applications, from endothelial and cardiomyocytic differentiation to neurocytic and osteogenic differentiation, due to their strong proliferation and wide differentiation potential (Figure 1) [7].

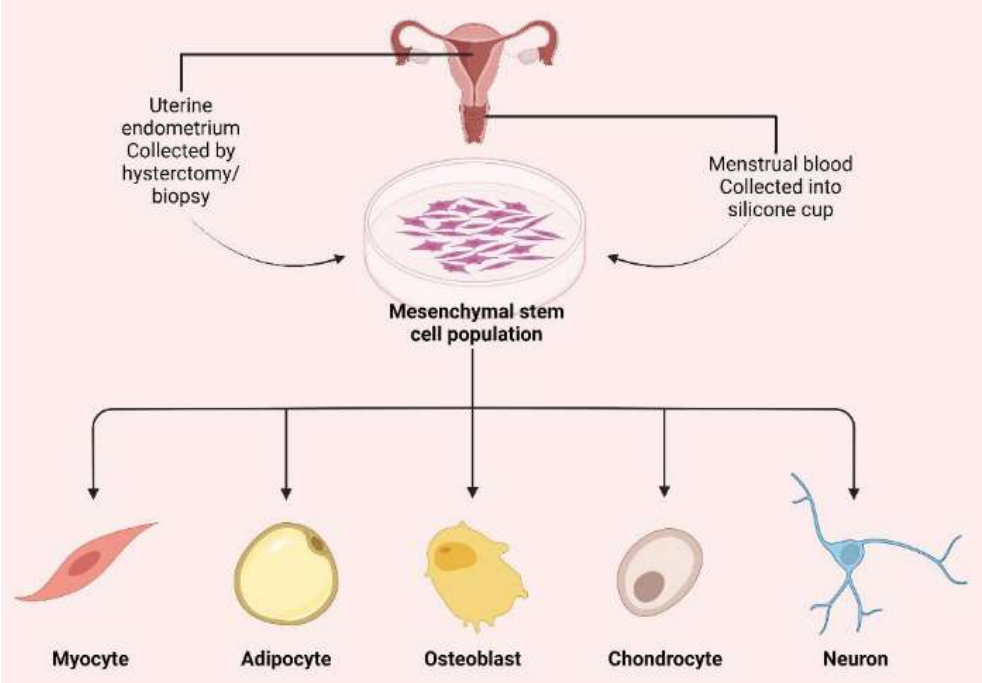

Figure 1: Isolation and culturing strategies of Menstrual Blood-Derived Stem Cells (MenSCs) and their potential to differentiate into various cell types and tissues [7]**.**

Menstruation

Menstruation is the outward sign of regular physiological uterine bleeding brought on by endometrial loss. In healthy, fertile women, it happens in a regular cycle lasting 28 to 30 days. In preparation for accepting a fertilized ovum, the uterus undergoes changes such as endometrial thickening, vascular system proliferation, and gland secretions. However, functional endometrial shedding occurs when a woman is unable to conceive; this is known as menstruation and is thought to be the "weeping of the uterus over the lost ovum" [8]. Menstruation has evolved from being a "monthly curse," as many women have said, to a "monthly boon," and the extraction of stem cells from menstrual blood has become a huge opportunity for regenerative medicine. Because of their immaturity, which allows for migration, growth factor secretions, cell differentiation, and immune modulation embedded with angiogenic potential, menstrual blood-derived stem cells are a promising source in stem cell research and have drawn the interest of researchers using them in restorative treatment approaches [9].

Importance of menstrual blood

- Tribal women placed some of the concealed blood clots to the wound after storing them in a tiny tube during their menstrual cycle. Because the clot caused the blood to coagulate in situ, the wound healed overnight and the bleeding ceased.
- Bollywood actress and stem cell recipient Lisa Ray was diagnosed with multiple myeloma in 2009. He has resumed his career today. This is because the stem cells gave it a second chance at life.
- There are a lot of self-renewing stem cells in menstrual blood. Any type of cell in the body can originate from stem cells.
- These menstrual blood stem cells have the rare capacity to differentiate into many kinds of healthy cells and are extremely proliferative.
- Oct4, SSEA4, Nanog, and ckit (CD117) are markers of stem cells in these cells.

- The issue of immunological rejection in female organ transplant recipients can also be resolved by mesenchymal stem cells obtained from menstrual blood.
- According to research, adult stem cells found in menstrual blood have the capacity to differentiate into nine distinct cell types: heart, lung, nerve, muscle, pancreatic, liver, fat, and bone cells.
- These cells have a faster rate of reproduction, according to researchers.
- Treatments for Alzheimer's disease, atherosclerosis, acute lung injury, liver cirrhosis, COPD, critical limb ischemia, and cardiac arrhythmia may benefit from the inclusion of stem cells found in menstrual blood.
- Additionally, menstrual blood is utilized in the arts and cosmetic applications including anti-aging therapies.

Stem cells and its features

Stem cells are homogeneous cells that have the capacity to develop into a variety of specialized bodily cells, such as brain, muscle, or blood cells. They are essential for tissue regeneration and repair because they have the capacity to self-renew and differentiate into additional stem cells or specialized cells.

- Capable of dividing and renewing themselves for extended periods of time.
- Possess the capacity to differentiate into distinct cell types.
- Blank cell(unspecialized)

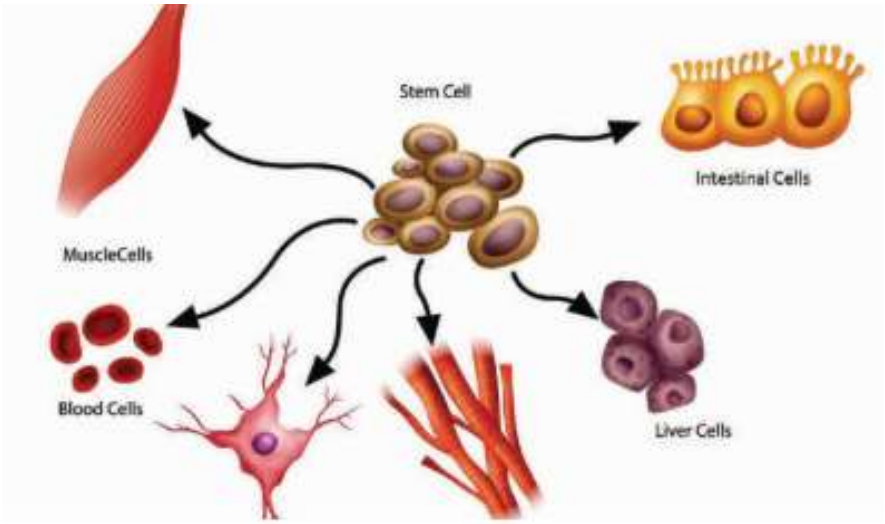

Figure 2: Stem cells [10]

Menstrual stem cells and advantages

The ability of stem cells in menstrual blood to differentiate into a variety of other healthy cell types is extremely proliferative. These priceless stem cells are discarded throughout a woman's menstrual cycle. These self-renewing stem cells are captured by Cryo-cell's menstrual stem cell banking service, which then processes and cryopreserves them for potential life-threatening cellular therapies. The endometrium, which lines the uterus, sheds more blood and tissues every month during a woman's menstrual cycle [11]. There are a lot of mesenchymal stem cells and growth factors in this uterine lining. These endometrial cells are distinct because they share several traits with both bone marrow and embryonic stem cells. The success rate of menstrual blood stem cells is 100 times more than that of human bone marrow stem cells, which range from 0.2 to 0.3%. It uses hematopoietic stem cell transportation to treat leukemia other disorders of non-hematopoietic tissue in a similar manner [12].

Advantages of menstrual blood stem cell

Menstrual blood stem cells, or MenSCs, are a new and promising source of stem cells with several potential applications in therapeutics and regenerative medicine. The following are some significant advantages of MenSCs:

- **Non-invasive extraction**: Unlike other stem cell sources like BM or AT, which need invasive procedures, menstrual blood collection is straightforward, painless, and nontoxic, making the process quick and comfortable for the donor.

- **Availability:** Monthly access to menstrual blood guarantees a reliable and repeatable source of stem cells.
- **Assured donor safety:** The collection of menstrual blood does not injure the donor, unlike other stem cell extraction techniques.
- **Rapid multiplication rate:** They can be preserved for extended periods of time without causing damage to their DNA, which can then be used for future study and treatment. They also have a high rate of multiplication.
- **Multipotent:** Osteocytes, chondrocytes, adipocytes, and neural cells are just a few of the many cell types that MenSCs can differentiate into. They are useful in regenerative medicine because of their capacity for differentiation, which may aid in the regeneration and repair of damaged tissues.
- **Immunoregulatory ability:** MenSCs have the ability to reduce immune responses, which helps treat autoimmune illnesses and lowers the rate of organ rejection during transplant procedures.
- **Cryopreservation:** MenSCs are preserved in liquid nitrogen, which ensures future use and can be kept for a longer amount of time without losing its potential.
- **Patient safety and security:** Because these cells are well tolerated and do not cause toxicity, adverse effects, or patient deaths, high patient safety is guaranteed.

Menstrual blood stem cells are a non-invasive, ethical, and adaptable source of stem cells with great potential for regenerative medicine and other therapeutic applications. They are a promising tool for improving medical research and creating novel treatments in the areas of wound healing, the neurological system, and the cardiovascular system because to their high proliferation rate, multipotency, and immunomodulatory qualities.

Technique for menstrual blood storage

Menstrual stem cells are kept in cryo vials that have been overwrapped to preserve them during storage. Managed-rate freezing is the term for this.

- **Processing:** Delivery of the sample to the laboratory within three to four hours is crucial during the processing phase. Stem cells are extracted after menstrual blood has been examined, processed, and separated.
- **Storage:** Menstrual stem cells are cryogenically kept at 196°C in a liquid nitrogen garage box to preserve them throughout time. By using a "controlled charge freezer" to regulate the chilling rate, this technique enables the stem cells to maintain their viability and efficiency even for decades in a cryopreserved form. During the storage term, the character has the right to use the preserved stem cells, and upon request, they can extend their privileges.
- **Retrieval:** In accordance with ICMR guidelines for approved therapeutic treatments and clinical trials, the character must submit a written request verified by the health professional's certification in order to obtain the stored stem cells.
- **Menstrual Blood Banks and Laboratories:** With more than 100 outlets distributed across 21 states, including Chennai and Gurgaon, Life Cellular is the main network for menstrual blood banking. It was created in Chennai, India. "Bangalore, Chandigarh, Hugli, Mysore, Aligarh, Pune, Ahmedabad, Mumbai, Hyderabad, Raipur, Warangal, Vijayawada, Jargon, Bhubaneswar", and more locations are all serviced by REE Lab & Lifestyles Cell Global Pvt Ltd.

Clinical Applications of Menstrual Blood Stem Cells (MenSCs)

Menstrual blood stem cells (MenSCs) represent a new, promising, and ethical source of adult stem cells with a broad range of therapeutic applications. Their high proliferation potential, multipotency, immune-modulatory properties and accessibility make them a promising option for a wide range of therapeutic applications [13]. The sections below showcase their important applications in key areas of medicine.

Regenerative Medicine

MenSCs are essential in regenerative medicine because of their capacity to differentiate into various cell types and aid in tissue regeneration. They can differentiate into osteogenic, chondrogenic, adipogenic, and even epithelial-like cells, making them an ideal choice for tissue repair. MenSCs promote faster wound healing by stimulating angiogenesis and collagen synthesis. Their secretome (secreted factors) containing growth factors and cytokines promotes cell growth and anti-inflammatory effects. Research has demonstrated their efficacy in skin wounds, burns and musculoskeletal injuries. And their use in bone and cartilage repair may have implications in osteoarthritis and fractures [14].

Neurological Disorders

MenSCs have demonstrated significant promise in the treatment of neurological conditions, thanks to their neuroprotective and regenerative effects. These cells can be induced to become neuron-like cells and produce neurotrophic factors, aiding in the survival and regeneration of neurons. For example, in stroke, MenSCs mitigate

neuronal damage and promote recovery by increasing blood supply and decreasing inflammation. They also aid in axonal regeneration and repair in spinal cord injuries. Recent studies also indicate their potential use in neurodegenerative conditions, like Alzheimer's and Parkinson's disease, where they might slow the progression of the disease by reducing inflammation and promoting regeneration [15].

Cardiovascular Diseases

MenSCs are mainly used for cardiac regeneration in the treatment of cardiovascular diseases. After a heart attack (myocardial infarction), the damaged cardiac tissues have poor regenerative capacity. MenSCs can overcome this barrier by promoting Angiogenesis and decreasing Fibrosis. They release growth factors like vascular endothelial growth factor (VEGF) that promote the development of new blood vessels, enhancing the delivery of blood to the ischemic region. Furthermore, they have anti-apoptotic properties that help to save cardiac cells. MenSC transplantation has been shown to improve heart function and limit infarct size in preclinical models, suggesting their therapeutic potential in heart diseases [16].

Reproductive Health

MenSCs are promising for reproductive applications because they are derived from the endometrium. They are particularly useful in endometrial repair and regeneration, and can be used to treat infertility and uterine diseases. MenSCs can regenerate endometrium, increase receptivity and improve implantation rates in women with Asherman's syndrome (intrauterine adhesions) and thin endometrium. They also hold promise for ovarian dysfunction and premature ovarian insufficiency, where they can help with ovaries and hormone production. Their application provides a new and minimally invasive treatment option for reproductive issues [17].

Metabolic and Autoimmune Diseases

MenSCs have robust immunosuppressive and anti-inflammatory effects, making them a good fit for metabolic and autoimmune conditions. MenSCs can modulate immune responses by reducing hyperinflammation and fostering healing. MenSCs have been tested in diabetes to enhance pancreatic function and insulin sensitivity. They can potentially regenerate pancreatic cells. In liver diseases, they help regrow liver cells and enhance liver function. In autoimmune diseases like rheumatoid arthritis and multiple sclerosis, MenSCs regulate immune responses, thereby decreasing disease activity and severity. This immune-modulating effect with minimal side effects makes MenSCs promising candidates for chronic inflammatory diseases [18].

LITERATURE REVIEW

(Feng & He, 2025) [19] examines the potential of MB in clinical applications and medical research, with an emphasis on its potential for diagnosis and treatment. MB provides a non-invasive sample technique for the identification of biomarkers in endometriosis, cervical cancer, and other gynecological disorders. Menstrual blood-derived stem cells, or MenSCs, are therapeutically intriguing candidates in regenerative medicine because they are pluripotent, have a high proliferation ability, and are low immunogenic. MenSCs are effective in treating intrauterine adhesions, hepatic illnesses, cutaneous injuries, neurological diseases, infertility, and premature ovarian insufficiency, according to preclinical and clinical research. By producing cytokines and exosomes that regulate immunity, reduce inflammation, and encourage tissue repair, MenSCs also have therapeutic benefits through paracrine pathways. MenSCs have great potential for creating innovative treatment approaches in a variety of disease domains, notwithstanding current obstacles.

(Chadha et al., 2024) [20] When a woman reaches menarche, her body naturally experiences menstruation as part of the reproductive cycle. However, stigma in a woman's life and several sociocultural factors have a significant impact. The discovery of mesenchymal stem cells in menstrual blood, which was formerly thought to be trash and filthy, has altered the idea. Researchers and medical professionals are drawn to a fresh method and given an alternative stem cell scope by the cell's unique capacity for self-renewal and differentiation. It seems that menstrual blood banking is a revolutionary, promising, economical, innovative, and morally acceptable alternative that has to be made more widely known in the medical field.

(Tamilnadu, 2024) [21] Women's menstrual blood was considered a waste when it came to banking and mending. waste of blood, although the majority of promising stem cells, which are produced from the cervix and vaginal series, have little value and entry. Menstrual blood stem cells, which are used to treat many diseases, including multiple myeloma and the use of anti-aging skin cream, are accumulating at the doorstep within three to four hours of arriving at the lab. Proper storage of these cells is a worry. Stash is applied to the wound in a clinical experiment and some menstrual blood clots. to stop the bleeding and cure the wound overnight Lisa Ray, a Bolly Timber actress and stem

mobile beneficiary, was diagnosed with multiple myeloma in 2009 and underwent treatment. Go back to the start of her life.

(Yahaya, 2024) [7] A novel and promising source of "mesenchymal stem cells (MSCs)" with significant potential in regenerative medicine is menstrual blood-derived stem cells, or MenSCs. Menstrual blood banking, which is in line with international trends and provides a sustainable, morally acceptable source of biological material for cutting-edge medical therapies, is discussed in this review along with the therapeutic potential of MenSCs. MenSCs' therapeutic potential and adaptability are being extensively investigated through clinical applications. However, there are other important factors to take into account while setting up MenSC banking, such as preserving stem cell procedure quality, assuring donor safety, and standardizing collection and isolation techniques. Additionally, ethical issues are crucial, especially in Islamic situations. Overcoming obstacles to standardization and addressing ethical issues in various cultural contexts are necessary for successful incorporation into clinical practice.

(Zhang et al., 2023) [22] By increasing the anti-apoptotic ability of ovarian cells, preventing ovarian follicular atresia, encouraging angiogenesis, and improving damaged ovarian structure and the pregnancy rate, mesenchymal stem cell (MSC)-based therapies have recently produced encouraging improvements in chemotherapy-induced ovarian dysfunction. MSC-derived biological factors, functional RNAs, and even mitochondria—which are either directly released or indirectly translocated with extracellular vesicles (microvesicles and exosomes) to correct ovarian dysfunction—are primarily responsible for these benefits. Menstrual blood-derived endometrial stem cells (MenSCs), a novel source of MSCs, have also shown encouraging therapeutic effects in a variety of diseases because of their many benefits, including regular donation and autologous transplantation, abundant stem cells, and non-invasive sample collection. As a result, this review reviews the effectiveness of MSC transplantation in reducing chemotherapy-induced POI, examines the underlying mechanism, and goes on to explore the advantages and current obstacles in advancing the clinical use of MenSCs in chemotherapy-induced POI.

(Pathrose et al., 2022) [23] The study's objective is to evaluate nursing students' knowledge about menstrual stem cell banking. A non-probability purposive sample strategy was used to choose 134 nursing students in order to assess their knowledge of menstrual stem cell banking. The study was conducted using a quantitative, descriptive research design. The data was gathered using an organized knowledge questionnaire. The survey found that most nursing students (89.6%) have a mediocre understanding of menstrual stem cell banking. 7.5% of nursing students had sufficient knowledge, whereas 3.5% had insufficient comprehension. The majority of nursing students at some Mangalore nursing schools had a mediocre understanding of menstrual stem cell banking, according to this poll.

(Faramarzi et al., 2016) [24] The purpose of this study was to separate the MenSCs and evaluate their capacity to differentiate into the epidermal lineage. The isolated MenSCs had a spindle-like form and stuck to the plate. The expression of mesenchymal markers CD10, CD29, CD73, and CD105 and the absence of markers for hematopoietic stem cells were found by flow cytometric analysis. There was early evidence of success in deriving the epidermal lineage from MenSCs. MenSCs can be employed non-invasively in a variety of dermatological applications to engineer differentiation to epidermal cells.

CONCLUSION

The practice of menstrual blood stem cell banking is a game-changing development in regenerative medicine that provides a renewable, non-invasive and ethically sound alternative source of stem cells. MenSCs have distinct characteristics such as high proliferation rates, multipotency, and immunomodulation, making them well-suited for various therapeutic uses. As outlined in this review, MenSCs show great potential for the treatment of a variety of diseases, such as neurological, cardiovascular, reproductive, metabolic and autoimmune diseases. Their therapeutic potential in tissue regeneration, inflammation suppression and regeneration enhancement highlights their clinical value. Improvements in cryopreservation and banking technologies also highlight the potential for future use of MenSCs. But the absence of standardized procedures and large-scale clinical trials, along with public awareness, hinder their adoption. These concerns need to be addressed through research, regulation and public education. In conclusion, the banking of menstrual blood stem cells is a technology of the future with the potential to provide novel, personalised and affordable treatment options in medicine.

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