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Exploring Stem Cell-Based Therapies for Veterinary Medicine: Opportunities and Challenges in Libya

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Abstract

This study explores the potential of stem cell technology in human and veterinary medicine, focusing on ethical challenges, preferred stem cell sources, and strategies for biobanking in Libya. An electronic survey of 500 participants from Arab countries assessed awareness, acceptance, concerns, and preferences regarding stem cell therapy. Most respondents (78%) had heard of stem cells, but only 21% had good knowledge, and 65% were willing to try stem cell therapy. The main concerns were health risks (47%), ethical issues (21%), and cost (18%), with a preference for adult and cord blood stem cells. The majority recommended awareness campaigns to improve public acceptance. The findings underscore the promise of stem cell applications and the need for education and ethical frameworks to support their use in Libya and the Arab region.

Keywords: stem cells, veterinary regenerative medicine, bio banking, pluripotent stem cells, veterinary surgery, ethical considerations

* INTRODUCTION

Stem cell biobanks serve as repositories for high-quality biological samples, supporting research in regenerative medicine, genetic studies, and therapeutic applications. In veterinary medicine, these biobanks play a critical role in advancing surgical techniques, particularly in orthopedics, wound management, and tissue engineering. Stem cell therapy offers solutions for conditions such as osteoarthritis, ligament injuries, and degenerative joint diseases in animals. By integrating stem cell banking into veterinary surgical practices, clinicians can enhance treatment outcomes and improve animal welfare.

The goal of stem cell biobanks is to collect high-quality samples include complete epidemiological, genetic, and clinical information. A common purpose is to support research projects that relate to genetic or genomic variables and difficult and complicated multi-factorial in human and animal diseases, as well as to examine how genes and the environment interact to affect our health. Standardization of sample collecting processes, technical processing, quality requirements, and the set of information recorded is essential for international research collaborations involving large numbers of individuals, allowing findings to be generalized across populations. It is important to establish quality criteria for such studies, including the nature of the sample, storage conditions, and the suitability of available data. In this study, we highlight stem cell biobanks and their function in regenerative medicine and community service.

The paradigm of stem cell biology is based on tissue-specific traits of self-renewal and pluripotency. Due to their self-renewal ability, stem cells replicate to build stem cell reservoirs in a differentiated state throughout life (He, Nakada, & Morrison, 2009; SLAC, 2018). Due to their pluripotency and multipotency, stem cells can give birth to a variety of specialized cells (SLAC, 2018).

Induced pluripotent stem cells (iPSCs) may now be created utilizing a variety of gene combinations (Wang, Bi, & Gao, 2017) and from a multitude of somatic cells (Avior, Sagi, & Benvenisty, 2016). The greater advantage of iPSCs is that they may be used to model human diseases in vitro, which can potentially be used to investigate the genetic cause of diseases and develop effective therapeutic drugs (Avior, Sagi, & Benvenisty, 2016). According to recent studies proving their variation, human iPSCs vary in their capacity to differentiate into specific branches. As a result, developing a more general differentiation approach to ensure the reliability of significant-scale applications and effective personalized treatments is a current issue (Ortmann & Vallier, 2017). The ability to create induced pluripotent stem cells (iPSCs) from patients, as well as the ability to differentiate these iPSCs into disease-relevant cell types, offers a new paradigm in drug research, one that places human disease pathophysiology at the center of preclinical drug development.

Several monogenic conditions have disease models created from iPSCs that show cellular disease patterns, but iPSCs can also be applied for phenotype-based drug screening in complicated diseases when the underlying genetic mechanism is unclear. The genetic and epigenetic stability of iPSCs and their relationship to embryonic stem cells, and also how this affects the fidelity of drug screening, are now being investigated. With a few exceptions, disease modeling has primarily concentrated on Mendelian diseases with a high clinical penetrance and recognized cellular pathophysiology, such as spinal muscular atrophy, familial dysautonomia, Rett syndrome, Hutchinson–Gilford progeria syndrome, and long QT syndrome. It's still unknown if iPSCs can be used to represent more complicated, irregular disease entities can be modelled with iPSCs remains uncertain (Wang, Bi, & Gao, 2017). Cell-based experiments allow for the discovery of new pathways as well as the identification of compounds with favorable cell permeability and toxicity profiles. Nevertheless, such studies are still less conducive to identifying the structure–activity connections that are critical for optimizing therapeutic characteristics.

iPSCs have significant benefits for drug toxicity screening against relevant human cells and tissues, and they may help in the establishment of "in vitro clinical trials" to evaluate the efficiency of medications or gene repair vectors against different patient genotypes. Human induced pluripotent stem cell (hiPSC) biobanks are significant resources for science and medical research because they provide a consistent supply of accessible cell lines that satisfy stringent quality and safety standards. HiPSCs are very valuable for studying disease processes, developing pharmacological models, and developing innovative therapeutic medicines. For clinical applications and drug development, it is critical that the obtained pluripotent cell lines never interact with animal-derived products or transplanted reagents (Good

Manufacturing Practice—grade), whereas Good Laboratory Practice conditions are acceptable for research purposes. Regardless of the final purpose, it is critical that every step in the process, beginning with the initial cells and continuing through expansion and alteration, be thoroughly performed and recorded.

Stem cell lines, particularly induced pluripotent stem cells (iPSCs), have emerged as a revolutionary tool in regenerative medicine and biomedical research. These cells, derived from adult somatic cells, can be reprogrammed to possess pluripotency, enabling them to differentiate into nearly any cell type in the body. This feature is invaluable in drug discovery, disease modeling, and cell-based therapies (Takahashi & Yamanaka, 2006; Smith, 2020).

The application of iPSCs in drug testing and disease modeling provides insights into the genetic and molecular mechanisms underlying various diseases. For example, iPSCs have been utilized to model neurological disorders Furthermore, iPSCs enable personalized medicine by generating patient-specific cell lines, offering a more accurate representation of disease and treatment responses (Sadeghian et al., 2021).

The community benefits of iPSC technology are profound. By generating disease-specific models, it is possible to accelerate the development of effective treatments for rare and complex conditions that have limited therapeutic options. Moreover, iPSCs can be used to generate tissues and organs for transplantation, addressing the growing organ shortage worldwide (Zhou et al., 2020). These advancements have the potential to significantly improve the quality of life for individuals suffering from degenerative diseases, genetic disorders, and other chronic health conditions.

In Libya, the application of stem cell technologies presents a unique opportunity to enhance healthcare and research capabilities. Establishing iPSC-based biobanks in Libya can facilitate collaborative research, not only addressing local health challenges but also contributing to global scientific advancements. For instance, the development of stem cell therapies could improve treatment options for common diseases in Libya, such as cardiovascular diseases, diabetes, and genetic disorders prevalent in the region (Elhaj et al., 2021). Furthermore, such initiatives could support veterinary medicine, particularly in animal health research, where stem cell therapies are showing promise for treating injuries and diseases in livestock and companion animals (Bertoni et al., 2020).

To implement these technologies effectively in Libya, strategic steps must be taken to build local capacity in stem cell research and biobanking. First, fostering international partnerships with leading research institutions and stem cell biobanks is crucial for knowledge transfer and technical support. Second, addressing the regulatory and ethical challenges surrounding stem cell research and therapy is essential to ensure the safe and effective application of these technologies. Lastly, public education and engagement are key to gaining community trust and support for stem cell-based therapies.

In conclusion, the application of stem cell lines, particularly iPSCs, offers immense potential for advancing medicine, improving public health, and addressing pressing medical challenges in Libya. By fostering the development of a robust stem cell research infrastructure, Libya can position itself as a leader in regenerative medicine, benefiting both human and veterinary health.

This study explores the role of stem cell biobanking in veterinary medical surgery, focusing on its application in tissue regeneration and wound healing. It examines the ethical and logistical challenges of establishing a biobank in Libya and its potential benefits for both veterinary and human medicine.

The research aims to: -

1- Investigate the development of a stem cell bank (SCB) to facilitate the use and transfer of high-quality stem cell lines for academic research and medical applications.

2- Review global best practices in veterinary stem cell biobanking and assess their applicability to Libya.

3- Propose strategies to establish and enhance stem cell biobanking in Libya, addressing local challenges and expanding the capacity for stem cell therapies.

4- Analyze the services offered by stem cell banks and their impact on the medical and research community.

*** A Literature Review**

Stem cell therapy has revolutionized modern medicine due to its regenerative potential. Stem cells are the body's "master" cells capable of self-renewal and differentiation into specialized cell types, making them invaluable in treating degenerative diseases and injuries. The distinction between stem cells and mature cells lies in their DNA organization—stem cells have inactive genes, while developed cells exhibit randomly structured active genes (Takahashi, 2006; Loh, 2006).

*** Stem Cell Applications in Medicine**

Abnormal differentiation or uncontrolled cell division is a primary cause of birth defects and cancers. Current stem cell therapies include treatments for spinal cord injuries, heart failure (Menasche, 2015), retinal degeneration (Schwartz, 2015), tendon ruptures, and type 1 diabetes (Ilic, 2017). Research into stem cell physiology may lead to novel therapies for presently untreatable diseases.

Stem cells contribute to tissue regeneration and immune system recovery. They can be derived from various sources, including bone marrow, adipose tissue, and umbilical cord blood. These cells have been successfully used to treat over 75 serious ailments such as hemophilia, thalassemia, blood cancers, and immune disorders (Wankhede, 2015).

*** Stem Cell Types and Sources**

Hematopoietic stem cells (HSCs) are crucial for blood cell generation and immune system support. They are harvested from bone marrow, peripheral blood, or umbilical cord blood. However, their application is limited due to low availability, difficulties in finding antigen-matched donors, and risks of immunoreactions or infections (Rocha, 2006). Induced pluripotent stem cells (iPSCs) provide a promising alternative by offering immune system compatibility and reducing transplant rejection risks.

Mesenchymal stem cells (MSCs) have gained significant interest due to their multipotent nature and differentiation capabilities. Initially sourced from bone marrow, MSCs are now also derived from adipose tissue, gingiva, skin, tonsils, and umbilical cords. Adipose-derived stem cells (ASCs) are particularly promising due to their abundance, ease of extraction, and minimal ethical concerns (Baer & Geiger, 2012). These cells have been successfully applied in treating degenerative and inflammatory diseases (Gonzalez et al., 2009; Constantin et al., 2009).

* Adult Stem Cell Types

Adult Stem Cell Types	Embryonic Origin	Living Tissue	Multipotency	References
Hematopoietic Stem Cells	Mesoderm	Peripheral blood, bone marrow, and umbilical cord blood	Hemopoietic stem cells generate both the myeloid (monocytes, macrophages, basophils, megakaryocytes, platelets) and lymphoid (T cells, B cells, and natural killer) blood cell lineages	(Riezzo, et al., 2017) (Eaves, 2015)
Bone Marrow Mesenchymal Stem Cells	Mesoderm	Bone marrow	These stem cells could be forced to divide into mesenchymal tissue lineages such as bone, cartilage, fat, tendon, muscle, and medullary stroma. Lately, researchers discovered that mesenchymal bone marrow stem cells may develop into cardiac, brain, and hepatocyte-like cells.	(Sakaguchi, et al., 2004) (Martino, et al., 2009)
Adipose Stem Cells	Mesoderm	Adipose tissue and lipoaspirate	The adipose stem cells have the ability to differentiate toward different cells of several tissues: fat, bone, cartilage, skeletal, smooth and cardiac muscle, endothelium, hematopoietic, and liver and neuronal.	(Fraser, Wulur, Alfonso, & Hedrick, 2006) (Nordberg & Loboa, 2015)
Dental Stem Cells	Mesoderm	Dental pulp	Dental stem cells can develop into mesenchymal (osteoblasts, adipocytes, chondrocytes, and myocytes) and non-mesenchymal tissue cells (neuronal and endothelial cells, hepatocytes, and melanocytes).	(Aghajani, et al., 2016)
Epidermal Stem Cells	Ectoderm	Epidermis and hair follicles	Epidermal stem cells have the ability to develop into cells from at least three specialized structures: the epidermis, hair follicles, and sebaceous glands.	(Watt & Lo Celso, 2006) (Ge, et al., 2017)
Neural Stem Cells	Ectoderm	Adult brain and spinal cord	Differentiated neurons, astrocytes, and oligodendrocytes are produced by neural stem cells.	(Gage, 2000)

* Emerging Trends and Challenges in Stem Cell Research

* Advances in Stem Cell Research

1- CRISPR-Based Gene Editing: Recent breakthroughs have leveraged CRISPR technology to precisely edit genes in stem cells, enhancing their functionality and therapeutic potential. This allows for the correction of genetic defects and the creation of disease models for research.

2 Improved Differentiation Techniques: Advances in protocols for directing stem cell differentiation have enabled the generation of more specialized and functional tissues. These improvements increase the reliability and safety of stem cell-derived therapies.

3- Stem Cell-Derived Organoids: The development of organoids—miniature, simplified versions of organs grown from stem cells—has provided powerful models for studying disease mechanisms, drug responses, and tissue development in vitro.

* Challenges in Clinical Applications

1- Ethical and Legal Concerns: Stem cell research, particularly involving embryonic stem cells, faces ongoing ethical debates and legal restrictions in various regions, which can limit research progress and clinical translation.

2- Biological Risks: Key risks include immune rejection of transplanted cells, the potential for tumor formation (teratomas), and incomplete or inappropriate differentiation of stem cells, all of which must be carefully managed before clinical use.

3- Cost and Accessibility: The high cost of developing, manufacturing, and administering stem cell therapies remains a significant barrier to widespread clinical adoption, especially in low- and middle-income countries.

*** The Role of Artificial Intelligence in Stem Cell Research**

1- Data Analysis and Differentiation Pathways: AI and machine learning tools are increasingly used to analyze large-scale datasets, helping researchers identify optimal pathways for stem cell differentiation and predict outcomes more accurately.

2- Predicting Stem Cell Behavior: Machine learning models can forecast how stem cells will behave under different conditions, improving the design and safety of regenerative medicine applications.

3- Automation and Scalability: Automated cell culture systems, powered by AI, enhance the reproducibility and scalability of stem cell production, making therapies more consistent and potentially more affordable.

Future Directions in the Arab World: -

1- Increased Funding and Government Support: Expanding financial investment and policy backing from governments can accelerate research and clinical translation of stem cell technologies in the region.

2- Collaboration and Capacity Building: Partnerships between local and international research institutions can foster knowledge exchange, improve infrastructure, and build expertise in advanced stem cell techniques.

3- Public Awareness and Acceptance: Initiatives aimed at educating the public about the benefits and safety of stem cell research can help overcome misconceptions and increase societal acceptance, paving the way for broader implementation.

*** Methods**

A cross-sectional survey was conducted to assess public awareness, acceptance, and preferences regarding stem cell therapy among individuals in several Arab countries. The survey instrument was developed based on a review of relevant literature and expert consultation to ensure cultural appropriateness and clarity. In addition to the original sections, the questionnaire included items specifically addressing perceptions of genetic and microbiome influences on stem cell therapy outcomes.

The questionnaire consisted of five sections: demographic information, knowledge of stem cells, attitudes and acceptance, genetic and microbiome influences, and recommendations. The survey was distributed electronically via social media platforms and email networks, targeting a random sample of 500 participants from diverse age groups, educational backgrounds, and Arab nationalities. Participation was voluntary and anonymous, and informed consent was obtained from all respondents.

The questionnaire included the following sections and sample questions: -

Section 1: Demographic Information

1- Age: (Under 20, 20–35, 36–50, over 50)

2- Gender: (Male, Female)

3- Educational level: (High school or below, University, Postgraduate)

4- Country of residence

Section 2: Knowledge of Stem Cells

5- Have you heard about stem cells before? (Yes / No)

6- What is your main source of information about stem cells? (Media, Internet, Physician, Family/Friends, I have not heard about them)

7- How would you rate your knowledge about the types and uses of stem cells? (Good, Moderate, Poor, None)

Section 3: Attitudes and Acceptance

8- Do you believe that stem cell therapy is safe? (Yes, No, Not sure)

9- Do you support the use of stem cells in the treatment of chronic diseases? (Yes, No, Not sure)

10- Would you be willing to try stem cell therapy if recommended by your physician? (Yes, No, Maybe)

11- What are your main concerns regarding stem cell therapy? (Health risks, Religious/ethical concerns, Cost, Ineffectiveness, No concerns)

Section 4: Genetic and Microbiome Influences

12- To what extent do you think genetic factors (such as inherited diseases or gene editing) affect the success of stem cell therapy? (Significant effect, Moderate effect, Little effect, No effect, Not sure)

13- Are you aware that the gut microbiome (the community of microorganisms in the digestive tract) can influence the outcomes of stem cell therapy? (Yes, No)

14- Would you support the use of genetic or microbiome screening before stem cell therapy to improve safety and effectiveness? (Yes, No, Not sure)

Section 5: Preferred Stem Cell Lines and Recommendations

15- Which types of stem cell lines do you believe are most appropriate for clinical use, considering ethical concerns?

1- Adult stem cells (from bone marrow, fat, etc.)

2- Umbilical cord blood stem cells

3- Induced pluripotent stem cells (iPSCs)

4- Embryonic stem cells

5- Not sure

16- What do you think is necessary to increase public acceptance of stem cell therapy? (Awareness campaigns, Government support, Lower cost, Safety assurances, Other)

*** Results**

A total of 500 individuals from various Arab countries participated in the survey, representing a balanced distribution across age groups and educational levels.

1- Knowledge of Stem Cells: 78% of respondents reported having heard about stem cells. However, 62% rated their knowledge as poor or moderate, while only 21% considered their knowledge to be good. The primary sources of information were the internet and media.

2- Acceptance of Stem Cell Therapy: 65% of participants expressed willingness to try stem cell therapy if recommended by their physician, 24% were uncertain, and 11% were unwilling.

3- Concerns: The most commonly reported concerns were related to health risks (47%), followed by religious or ethical issues (21%), high cost (18%), and doubts about effectiveness (14%).

3- Genetic Influence: 59% of respondents believed that genetic factors have a significant or moderate effect on the success of stem cell therapy. Many participants recognized the importance of gene editing and genetic compatibility, especially for inherited diseases. There was general support for integrating genetic screening to enhance therapy outcomes .

4- Microbiome Influence: 34% of participants were aware that the gut microbiome can influence stem cell therapy outcomes. After providing a brief explanation, 68% supported the idea of microbiome screening or modulation (such as probiotics) before therapy to improve safety and effectiveness. Awareness of the microbiome's role was higher among those with medical or scientific backgrounds. Recent research highlights that microbiome diversity is linked to better engraftment, lower infection rates, and improved survival after stem cell transplantation .

5- Preferred Stem Cell Lines: When asked about the most appropriate stem cell lines for clinical use with minimal ethical concerns:

1- 54% preferred adult stem cells (from bone marrow, fat, etc.)

2- 28% selected umbilical cord blood stem cells

3- 12% favored induced pluripotent stem cells (iPSCs)

4- Only 6% supported the use of embryonic stem cells

6 Recommendations: The majority of respondents (72%) emphasized the need for public awareness campaigns to improve understanding of stem cell therapy. Additionally, 58% advocated for increased government support to reduce costs, and 36% highlighted the importance of safety assurances to foster public trust.

*** Statistical Analysis of Survey Results**

To enhance clarity and facilitate graphical representation, all survey findings are consolidated into two comprehensive tables: one for knowledge, acceptance, and genetic/microbiome influence, and another for concerns, stem cell line preferences, and recommendations.

Table 1: Knowledge, Acceptance, and Genetic/Microbiome Influence

Aspect	Percentage (%)
Awareness of stem cells	78
Good knowledge	21
Willingness to try therapy	65
Genetic influence awareness	59
Microbiome influence awareness (pre)	34
Microbiome influence awareness (post)	68

Table 2: Concerns, Stem Cell Line Preferences, and Recommendations

Category	Percentage (%)
Health concern	47
Ethics concern	21
Cost concern	18
Adult stem cells	54
Cord blood stem cells	28
Induced pluripotent stem cells	12
Embryonic stem cells	6
Need for awareness campaigns	72

*** Graphical Representation**

The following grouped bar charts visually summarize the key findings from both tables, making it easier to compare trends in knowledge, acceptance, genetic/microbiome influence, concerns, stem cell line preferences, and recommendations.

Grouped bar charts summarizing survey results: -

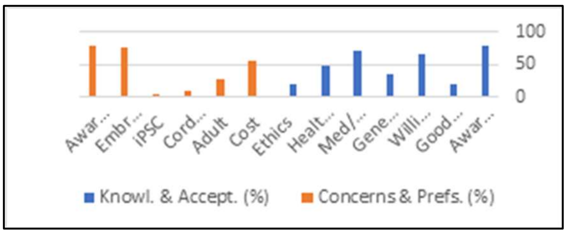

Figure1 shows: (1) Knowledge, Acceptance, and Genetic/Microbiome Influence; (2) Concerns, Stem Cell Line Preferences, and Recommendations.

*** Key Insights**

1- Awareness and Acceptance: High general awareness (78%) contrasts with lower levels of in-depth knowledge (21%), while willingness to try therapy is moderate (65%).

2- Genetic and Microbiome Factors: Over half of respondents recognize the importance of genetic factors (59%), and support for microbiome screening increases significantly after explanation (from 34% to 68%).

3- Concerns: Health risks are the most cited concern (47%), followed by ethical (21%) and cost (18%) issues.

4- Stem Cell Line Preferences: Adult and cord blood stem cells are most preferred (54% and 28%), with minimal support for embryonic sources (6%).

5- Recommendations: A strong majority (72%) emphasize the need for awareness campaigns to improve public understanding and acceptance.

*** Statistical Insights**

1- High Awareness, Low Depth: While 78% of respondents have heard of stem cells, only 21% report good knowledge, indicating a gap between general awareness and in-depth understanding.

2- Acceptance Linked to Knowledge: 65% are willing to try stem cell therapy, suggesting moderate acceptance, possibly influenced by knowledge levels and trust in medical advice.

3- Health Concerns Dominate: Health risks are the most cited concern (47%), followed by ethical (21%) and cost (18%) issues.

4- Genetic and Microbiome Factors: 59% recognize the importance of genetic factors, and support for microbiome screening rises from 34% (pre-explanation) to 68% (post-explanation), reflecting openness to scientific advances when properly informed.

5- Ethically Preferred Sources: Adult and cord blood stem cells are most preferred (54% and 28%, respectively), with minimal support for embryonic sources (6%), highlighting ethical considerations in public opinion.

6- Strong Demand for Education: 72% call for awareness campaigns, underlining the need for targeted educational initiatives to address misconceptions and build trust.

These tables and insights provide a comprehensive statistical overview of the survey results, supporting evidence-based recommendations for policy and public engagement in stem cell therapy.

* **Discussion**

The results of recent studies and the current state of veterinary stem cell research in Libya highlight both the promise and the challenges of this emerging field. The application of mesenchymal stem cells (MSCs) in veterinary medicine has shown encouraging outcomes in the management of musculoskeletal injuries, neurological disorders, and immune-mediated diseases in animals. These findings are consistent with global trends, where MSCs derived from bone marrow, adipose tissue, and umbilical cord blood have demonstrated the ability to differentiate into multiple cell types, supporting tissue regeneration and improved healing in various animal models.

In Libya, the early adoption of stem cell therapy in veterinary practice is a significant step forward, especially given the importance of livestock, horses, and companion animals to the country's agricultural and healthcare sectors. The initial research efforts suggest that stem cell-based therapies could offer more effective management of chronic conditions such as osteoarthritis, tendon injuries, and spinal cord disorders, which are prevalent in both working and companion animals. These advances have the potential to enhance animal welfare, productivity, and the economic value of livestock.

However, the results also underscore several challenges that must be addressed to fully realize the benefits of stem cell therapies in Libya: -

1- Resource Limitations: There is a need for greater investment in laboratory infrastructure, equipment, and skilled personnel to support advanced stem cell research and clinical applications.

2- Regulatory and Ethical Frameworks: The absence of clear guidelines and regulations for the use of stem cells in animals poses ethical and legal challenges. Developing robust policies that ensure animal welfare and address public concerns is essential.

3- Access to Technology: Limited access to cutting-edge technologies and reagents can hinder the progress of research and the translation of findings into clinical practice.

4- Awareness and Training: Increasing awareness among veterinarians, animal owners, and policymakers about the potential and limitations of stem cell therapies is crucial for their acceptance and responsible use.

Despite these obstacles, the positive attitudes among veterinary professionals and the growing interest in stem cell research provide a strong foundation for future development. International collaborations and partnerships with established research centers can help bridge gaps in expertise and resources, accelerating the adoption of best practices and innovative therapies.

*** Conclusion**

Stem cell therapy represents a transformative opportunity for veterinary medicine in Libya, with the potential to revolutionize the treatment of a wide range of animal diseases and injuries. The early results are promising, particularly in the management of musculoskeletal and neurological disorders, which are common and often debilitating in animals.

To harness the full potential of stem cell-based therapies, it is imperative to address the scientific, ethical, and logistical challenges identified in the current research landscape. This includes investing in research infrastructure, developing comprehensive regulatory frameworks, and fostering a culture of ethical responsibility in the use of stem cells.

Collaboration among veterinary professionals, researchers, and government authorities will be key to establishing the necessary infrastructure and regulatory environment. International partnerships can further enhance local capabilities and ensure that Libyan veterinary medicine remains aligned with global standards.

Ultimately, with sustained effort and strategic investment, stem cell therapies can become an integral part of veterinary healthcare in Libya, improving animal health, supporting the agricultural sector, and benefiting animal owners and society as a whole.

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