Stem cells – a medical revolution

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European Journal of Medical Technologies
2016; 4(13): 6-11

www. medical-technologies.eu
Published online 31.12.2016

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Abstract

Stem cells represent a large and very diverse category of cells whose purpose is to change from one type of cell to another. They are characterized by stability to an unlimited number of divisions for an indefinite time throughout the life of the organism. Stem cell are undifferentiated cells capable of self- renewing. They are ubiquitous in many tissues and organs of the human body, and some of them are the real regenerative geniuses.

At the end of the twentieth century many pioneering discoveries were made that make the potential use of stem cells in the treatment of many diseases more probable. Today, both in Poland and around the world range of treatments is carried out using stem cells. They have become a great tool to meet the timeless human desire to improve the quality and length of life. Used in clinical practice they gave hope to many patients that effective methods of treatment for many diseases so far incurable by traditional methods will be developed. You can certainly say that they are the most powerful tool of modern science

Key words:

stem cells, umbilical cord blood , medicine

Introduction

Stem cells are a large and diverse category of cells capable of differentiating into other cell types [1]. Their key characteristic is their ability to last through an unlimited number of cell division cycles – i.e. self-renewal throughout the life of the organism. Stem cells are undifferentiated, self-renewing, and proliferating, thus ensuring, for example, a lifetime supply of stem cells required for hematopoiesis in the bone marrow, which in turn ensures adequate production of blood cells needed by a given organism [2]. Apart from the above-mentioned characteristics, stem cells have another feature that enables their use in medicine, which is their capability of developing into various specialized daughter cells required to compensate for losses due to the aging of mature cells [3]. Stem cells are present in many human tissues, enabling their repair in case of damage or wear. Another characteristic of stem cells is plasticity, meaning the ability to differentiate into cells of a germ layer other than the one they originate from – i.e. changing their lineage, together with their physical and functional characteristics. This process is called transdifferentiation and occurs e.g. in blood stem cells that transform into liver cells [2].

In humans, stem cells reside in a multitude of locations [4], including the placenta and umbilical cord; peripheral blood; dermis; olfactory bulbs – the pair of Q-shaped organs located behind the eyes. Stem cell activity has been found in bones, in muscular connective tissue, at the intestinal wall. Large quantities of stem cells are present in the brain, heart, lungs, pancreas, thymus, spleen, liver, and kidneys. Bone marrow is a niche for stem cells, and more precisely, for one of their most common types – hematopoietic stem cells [2,5].

Stem cells reside in most human organs, and some types have exceptional regenerative capabilities. Based on their origin, stem cells can be identified as embryonic SCs, fetal SCs, cord blood SCs, and somatic SCs [2].

Stem cells are considered highly heterogeneous in terms of potency. In descending order, they can be classified as:

1. Totipotent – unique cells with the broadest capabilities for development. A fertilized ovum, i.e. a zygote, is an example. Totipotency entails the capability of forming a new independently viable organism [6,7].
2. Pluripotent – cells with a high differentiation potential, descending from totipotent cells. They are found e.g. in the morula and in the blastocyst. They can differentiate into cells derived from all the three germ layers, i.e. mesoderm, ectoderm, or endoderm, including reproductive cells [8,9,10,11].
3. Multipotent – cells capable of differentiating into specialized cells, but with a narrower spectrum of possible outcomes than in the case of pluripotent cells. They transform into cells with similar properties and embryonic origins [7,12,13].
4. Unipotent – cells that only act as precursors of functional cells, the final stage of stem cell development [14]. They have a set lifetime, and their differentiation potential is restricted to a specific cell type [8,11,12].

Based on their origin, stem cells can be classified as:

1. Embryonic (*ES cells*) – versatile cells first discovered over 20 years ago. They are derived from the inner cell mass of an early-stage embryo that will later form the three germ layers [7,15]. They can be both totipotent and pluripotent, capable of differentiating into any type of somatic cells [3,6,11].
2. Fetal – multipotent stem cells derived from fetal tissues and blood, especially in the first trimester of pregnancy. They have a decreased expression of transplant antigens, which greatly reduces risk of transplant rejection by the recipient's immune system [10,11,12]. Mainly found in the bone marrow, lungs, liver, kidneys, pancreas, placenta, and CNS. Their harvesting is mainly limited by ethical considerations, as they are typically obtained from aborted fetuses [6,9,11].
3. Adult – also called somatic stem cells. Present in many tissues of the developed organism, they can be pluripotent, multipotent, or unipotent. Totipotent adult stem cells are rare, but can be found in bone marrow [4,9,16]. The primary and most researched source of adult stem cells, used in medicine for more than 40 years, is bone marrow [6,11,17]. Peripheral blood is also rich in adult stem cells, and has recently become widely used as a source of hematopoietic stem cells for transplantation purposes. Another abundant and increasingly popular source of adult stem cells is the adipose tissue. Adipose stem cells are mainly obtained in cosmetic liposuction procedures

[3,6,11]. Adult stem cells are used to a limited extent due to difficulties in identification and extraction. Moreover, they grow slowly, and their culture involves much effort, expense, and difficulty [3,9,16]. Somatic stem cells seem to be less versatile than embryonic ones. However, some types have proven useful in inducing limited regenerative and reparative effects. There is hope for fuller use of somatic stem cell potential in the future [3].

4. Cord blood_ is an alternative to peripheral blood and bone marrow as a source of stem cells. It is obtained after delivery from the placenta and the attached umbilical cord [7,11,18]. These cells are relatively easily accessible and have a high differentiation potential. However, relatively few cells are obtained from cord blood, which restricts their medical uses [18,19,20]. These stem cells can differentiate into various types of cells, have a high division potential, and their culture involves relatively small requirements [6,11,18]. Low antigen expression means that they are associated with a lower risk of graft rejection by the recipient's immune system. Cord blood contains different types of stem cells: hematopoietic, mesenchymal, and a most potent type resembling embryonic stem cells [18,20,21]. The latter are more primitive and less restricted in terms of differentiation than somatic stem cells; they also have a high proliferative potential. Due to their characteristics, they have found uses in transplantation, as an alternative to the most commonly used stem cell source, which is bone marrow. Cord blood is mainly used for treating hematopoietic diseases and primary bone marrow disorders [8]. Recent studies opened up new possibilities for its use in regenerative medicine, which means it could potentially be used in the future to treat neurodegenerative disease [1,6,11].

Cord blood collection is a simple and non-invasive procedure. Cord blood preserved during delivery enables the necessary biological material to be quickly obtained in case transplantation is indicated [2,6,20,22,23]. Correctly collected, transported, analyzed and prepared cord blood can be stored and used in treatment of numerous diseases. Cord blood can only be collected once in a lifetime – during delivery, in a procedure only taking minutes. After the umbilical cord is cut, the umbilical vein is cannulated and the blood remaining in the afterbirth flows into the collection kit, comprised of a solid styrofoam container lined with bags containing a temperature-control substance [22,23].

Cord blood is a rich source of stem cells with a high proliferative potential [6,11,20]. For this reason it is stored in the so-called stem cell banks, where it is used not only as interesting research material, but also as a valuable clinical resource [17]. The first Polish institution aiming to provide a state-of-the-art preservation and storage service for stem-cell-rich cord blood was the Polish Stem Cell Bank (Polski Bank Komórek Macierzystych, PBKM), established in 2002 [18]. Currently, a number of cord blood banks operate in Poland, both commercial (private) and public. Since the first successful transplantations of cord blood stem cells, proving that the cryopreserved cells retain their proliferative properties and potential for hematopoiesis reproduction, over 130,000 units of cord blood have been banked worldwide [18].

Currently, stem cells are considered an instrument in humans' eternal quest for better and longer life [10]. Over 40 years of clinical experience with stem cell use gave patients tremendous hope for effective treatments for a number of previously untreatable diseases [16]. The first therapeutic uses of fetal stem cells date back to the 1980s, when the method was explored by researchers looking for Parkinson's disease treatments. Regardless of their source, stem cells are considered a great hope in medicine, and they are already being used, both in Poland and worldwide, in a range of procedures. Interest in stem cells is linked especially to their potential usefulness in cardiovascular treatment. Despite the incomplete knowledge on stem cells we currently have, many hospitals, also in Poland, perform procedures using stem cells for myocardial regeneration [15,19].

Recently it has been proven that cord blood and bone marrow stem cells can serve as a reservoir of nerve cells. The first reports of the presence of stem cells in the CNS, from 2003, confirmed the hypothesis that the human brain is not a static organ incapable of repair or growth [12,18]. The discovery of neural stem cells offers hope for future use of such cells in repairing nerve, brain, or spinal cord damage. Detailed results have been obtained with regard to stem cell treatment in young patients with spinal cord injury [12,15]. Locally administered stem cells created conditions conducive to axon repair, especially in patients with spinal cord rupture. The regeneration of damaged nerves in humans is considered one of the ultimate goals in medicine [12].

The human dermis is an abundant source of stem cells that maintain stable numbers through subsequent division cycles and give rise to a population of highly proliferative cells. In recent years, researchers discovered hair stem cells in the dermis that seem potentially useful in cosmetic procedures [16,26]. Studies suggest that potential exists for the use of stem cells in treatment of patients with trophic ulcers or skin cancer [2,16]. Research on the use of adipose stem cells for breast reconstruction or after myomectomy procedures is underway. As adipose stem cells can be easily extracted, their use for accelerating healing of bone and cartilage damage is increasingly common [2,27,28]. Recently, use of stem cells in treatment of type 1 diabetes mellitus, affecting over 5 million young patients worldwide, has been reported [17,25]. This types of procedures involve extraction of stem cells from the diabetic patient's blood, followed by chemotherapy and a stem cell transfusion. This treatment, termed autologous hematopoietic stem cell transplantation, has proven effective e.g. in treatment of rheumatoid arthritis or Crohn's disease [1,25]. Stem cell therapy is also used to assist cancer treatment (kidney cancer). As to mesenchymal stem cells, they can be administered locally to enhance healing of fractured bones, e.g. in osteoporosis, or in bone transplant procedures. These cells also have a diagnostic use [2,19]. Fertility clinics worldwide use an effective method of human embryo screening called preimplantation diagnosis. Stem cells undoubtedly have great potential for use in treatment and are sure to play an important role in medicine [19]. They are the most powerful instrument of today's science. However, before their full potential can be unlocked, further research is necessary [2].

Is the use of stem cells ethically sound?

The possible use of versatile stem cells in transplantation is a recent discovery, giving rise to a number of concerns [29]. From an ethical perspective, their use is largely uncontroversial, especially with regard to their therapeutic potential. Any concerns would be related to potential risks of incorrect administration of stem cells into damaged or diseased organs, leading to neoplasia [30]. Ethical questions are however raised by stem cell harvesting and culturing [29]. Issues related to methods of stem cell collection are mainly associated with pluripotent cells, which, despite no longer having the highest potency, can proliferate to an unlimited extent. These cells are harvested from miscarried human fetuses or from 4–6 day-old extra embryos produced in IVF procedures. Here, a fundamental problem arises – the collection of stem cells destroys the embryo, which, whether as a morula or a blastocyst, is not just an aggregation of cells or a part of the mother's body, but clearly constitutes a new human being [5,29,30].

In accordance with current medical knowledge, from the moment of conception the embryo has its separate identity and DNA, meaning the conception is a beginning of a new life – not that of the male and female reproductive cell donors, but of a new human being. The Catholic Church defends the right to life, strongly expressing the view that human life begins at conception. If human life, not as a mere biological being, but rather as a biological and spiritual one – as a person – develops continually since conception, then termination of this life at any stage must be viewed as homicide. By defending the Christian concept of the embryo, one defends all human beings, as the accepted view shapes the scope of protection of human dignity and guaranteed fundamental rights [31,32,33]. For most ethicians, the irreversible destruction of a human embryo is equivalent to killing a human being [6].

One argument taking root in modern bioethics is the "slippery slope" argument put forward by opponents, describing a situation where return or a change in views becomes impossible. This means that if certain actions, experiments or techniques are allowed, their continuation can no longer be prevented at a later point. What the slippery slope argument entails is that people should stop the use of morally-ambiguous techniques, as consequences are difficult to predict, and care must be taken not to go a step too far. For example, if experimentation on human embryos is allowed, sooner or later the killing of human fetuses will also be accepted [6].

Conclusion

The area of stem cell research is associated with specific terminology, revealing a certain attitude to issues of embryonic stem cell use. Proponents of therapeutic cloning often use terms such as preembryo, embryo, genetic material, or additional material, while advocates of humanity speak of human beings, embryos having human dignity, and carriers of life. If researchers find an ethically-acceptable source of stem cells, there will be no obstacles to their therapeutic use. Such promising and, importantly, ethically correct, sources of stem cells may include: the dermis, cord blood, bone marrow, and nervous system. For the past several years, researchers have been trying to successfully "reprogram" somatic cells into cells similar to embryonic stem cells. Despite the extreme difficulty associated with procedures for obtaining stem cells, they seem to heed one very important principle – that not everything that is technically possible is also morally good. Therefore, the future course of action must consider the inadmissibility of certain research activities [6].

References

1. Witoń M. Komórki macierzyste. Laboratorium medyczne 2007; (7-8): 51-52.
2. Scott ChT. Czas komórek macierzystych. Krótki wstęp do nadchodzącej medycznej rewolucji. Wyd. CKA, Gliwice 2008.
3. Banaś A. Komórki macierzyste – perspektywy i zagrożenia. Przegląd Medyczny Uniwersytetu Rzeszowskiego 2010; 2: 117-127.
4. Kawiak J. Komórki macierzyste organizmu dorosłego w biologii i medycynie. Postępy Biologii Komórki 2009; TOM 36, supl. XXV: 99-110.
5. Chyrowicz B. Moralne kontrowersje wokół badań nad komórkami macierzystymi. Postępy Biologii Komórki 2005; 32, supl. 23: 89-103.
6. Baum E. Komórki macierzyste jako bioetyczny problem współczesnej medycyny. Wyd. AM Poznań, Poznań 2010.
7. Ciemierych M.A. Zarodkowe komórki macierzyste – w poszukiwaniu pluripotencji. Postępy Biologii Komórki 2008; 35: 183-205.
8. Bruczkowski D. Krew pępowinowa. Przeszłość, teraźniejszość, przyszłość. Gin Pol Medproject 2009, 4: 73-82.
9. Olszewska-Słonina DM, Styczyński J, Drewa TA, et al. Komórki niezróżnicowane – źródła i plastyczność. Advances in Clinical Experimental Medicine 2006, 497-503.
10. Ratajczak MZ, Machaliński B, Czajka R, et al. Konsekwencje fizjologiczne i patologiczne występowania komórek linii zarodkowych w dorosłych tkankach, Ginekologia Polska 2009; 80: 935-941.
11. Baum E, Musielak M, Komórki macierzyste – biologiczne aspekty medycyny regeneracyjnej. Ginekologia i Położnictwo 2008; 4: 63-73.
12. Machaliński B. Nieembrionalne komórki macierzyste, a regeneracja układu nerwowego. Polski Przegląd Neurologiczny 2008; 1(4): 15-19.
13. Biesaga T. Komórki macierzyste i klonowanie człowieka – nadzieje i zagrożenia. Etyka 2004; 10: 21-29.
14. Kolanowski T, Kurpisz M, Indukowane pluripotencjalne komórki macierzyste – geneza, problemy oraz perspektywy wykorzystania w terapii chorób serca. Kardiologia Polska 2010; supl. V: 412-417.
15. Przybycień K, Kornacewicz-Jach Z, Machaliński B, Komórki macierzyste w klinicznych badaniach kardiologicznych. Kardiologia Polska 2011; 69 (6): 601-609.
16. Drukala J, Majka M, Ratajczak M, Metody izolacji i namnażania komórek macierzystych naskórka ludzkiego. Postępy Biologii Komórki 2003, TOM 30, supl. XXI: 37-48.

17. Sikora MA, Olszewski WL. Komórki macierzyste – biologia i zastosowanie terapeutyczne. Postępy Higieny i Medycyny Doświadczalnej 2004; 58: 202-208.
18. Stolarek M, Myśliwski A. Komórki macierzyste krwi pępowinowej. Postępy Biologii Komórki 2005; 2 (32): 375-390.
19. Kamieniarz K, Nawrot R, Grajek K, et al. Biotechnologia w medycynie regeneracyjnej i reprodukcyjnej. Biotechnologia 2006; 2: 31-48.
20. Roszek K, Komoszyński M. Kontrola i kierunki różnicowania komórek macierzystych krwi pępowinowej oraz ich zastosowanie terapeutyczne. Postępy Higieny i Medycyny Doświadczalnej 2008; 62: 660-667.
21. Pojda Z, Machaj EK, Gajkowska A, et al. Badanie potencjalnej przydatności klinicznej komórek macierzystych uzyskiwanych z krwi pępowinowej. Postępy Biologii Komórki 2005; 32, supl. XXIII: 127-137.
22. Iwanowicz-Palus GJ, Bałanda A. Pobieranie krwi pępowinowej do banku komórek macierzystych. [W:] Bałanda A. [red.]. Opieka nad noworodkiem. Wyd. Lekarskie PZWL, Warszawa 2008, s.184-188.
23. Pilonis H. Pępowinowy marketing. Służba zdrowia. 2010, 93-100.
24. Opiela J. Mezenchymalne komórki macierzyste w transplantologii. Wiadomości Zootechniczne 2012: 3: 37-43.
25. Pikuła M, Trzonkowski P. Biologia komórek macierzystych naskórka oraz ich znaczenie w medycynie. Postepy Hig Med Dosw. (online) 2009; 63: 449-456
26. Gawrylska E, Grafka A, Putowski L, Łopucki M, Roliński J. Komórki macierzyste w leczeniu złamań towarzyszących osteoporozie – medyczne science fiction czy metoda terapii w przyszłości? Przegląd Menopauzalny 2011, 5: 378-382.
27. Jezierska-Woźniak K, Nosarzewska D, Tutas A, Mikołajczyk A, Okliński M, Jurkowski MK. Wykorzystanie tkanki tłuszczowej jako źródła mezenchymalnych komórek macierzystych. Postepy Hig Med Dosw. (online) 2010; 64: 326-332.
28. Dąbska M. Bioetyka, a postęp badań naukowych. Medycyna Wieku Rozwojowego. 2001; supl. I: 45-47.
29. Hołub G. Etyczna refleksja na temat komórek macierzystych. Sosnowieckie Studia Teologiczne 2007; TOM VIII: 49-60.
30. Morciniec P. Ocalić obraz człowieka: istota dyskusji o komórkach macierzystych. [W]: Morawiec Z. [red.]: Ocalić cywilizację – ocalić ludzkie życie. Wyd. Księży Sercanów, Kraków 2002, 119-129.
31. Biesaga T. Komórki macierzyste i klonowanie człowieka – nadzieje i zagrożenia. Medycyna Praktyczna 2004; 10: 21-25.
32. Jabłońska MK, Frączek PE, Siwczyńska D, Pacian A, Skórzyńska H, Pacian J. Embrion – istota ludzka czy tylko zapłodniona komórka jajowa? Hygeia Public Health 2012; 47(3): 277-282.