NEURAL REGENERATION RESEARCH
Volume 7, Issue 22, August 2012
www.nrronline.org

Cite this article as: Neural Regen Res. 2012;7(22):1744-1751.

Stem cell transplantation for treating Duchenne muscular dystrophy

A Web of Science-based literature analysis

Xiaofeng Yang

Cell Therapy Center, Chinese PLA 463 Hospital, Shenyang 110042, Liaoning Province, China

Abstract

OBJECTIVE: To identify global research trends in stem cell transplantation for treating Duchenne muscular dystrophy using a bibliometric analysis of Web of Science.

DATA RETRIEVAL: We performed a bibliometric analysis of studies on stem cell transplantation for treating Duchenne muscular dystrophy from 2002 to 2011 retrieved from Web of Science.

SELECTION CRITERIA: Inclusion criteria: (a) peer-reviewed published articles on stem cell transplantation for treating Duchenne muscular dystrophy indexed in Web of Science; (b) original research articles, reviews, meeting abstracts, proceedings papers, book chapters, editorial material, and news items; and (c) publication between 2002 and 2011. Exclusion criteria: (a) articles that required manual searching or telephone access; (b) documents that were not published in the public domain; and (c) corrected papers.

MAIN OUTCOME MEASURES: (1) Annual publication output; (2) distribution according to subject areas; (3) distribution according to journals; (4) distribution according to country; (5) distribution according to institution; (6) distribution according to institution in China; (7) distribution according to institution that cooperated with Chinese institutions; (8) top-cited articles from 2002 to 2006; (9) top-cited articles from 2007 to 2011.

RESULTS: A total of 318 publications on stem cell transplantation for treating Duchenne muscular dystrophy were retrieved from Web of Science from 2002 to 2011, of which almost half derived from American authors and institutes. The number of publications has gradually increased over the past 10 years. Most papers appeared in journals with a focus on gene and molecular research, such as *Molecular Therapy*, *Neuromuscular Disorders*, and *PLoS One*. The 10 most-cited papers from 2002 to 2006 were mostly about different kinds of stem cell transplantation for muscle regeneration, while the 10 most-cited papers from 2007 to 2011 were mostly about new techniques of stem cell transplantation for treating Duchenne muscular dystrophy.

CONCLUSION: The publications on stem cell transplantation for treating Duchenne muscular dystrophy were relatively few. It also needs more research to confirm that stem cell therapy is a reliable treatment for Duchenne muscular dystrophy.

Key Words

pseudohypertrophic muscular dystrophy; Duchenne muscular dystrophy; Becker muscular dystrophy; stem cell; myoblast; exon skipping; dystrophin gene; motor function; cell transplantation; regenerative myogenesis; neural regeneration

Research Highlights

(1) We performed a bibliometric analysis of published studies on stem cell transplantation for treating Duchenne muscular dystrophy from 2002 to 2011 retrieved from Web of Science.
(2) We analyzed the distributions according to institutions in China and according to institutions that cooperated with Chinese institutions to provide information on the research status in China.
(3) We analyzed the most-cited articles from 2002 to 2006 and from 2007 to 2011 to identify changes in research focus regarding the use of stem cell transplantation for Duchenne muscular dystrophy over the past 10 years.

Xiaofeng Yang, Chief physician, Master's supervisor, Cell Therapy Center, Chinese PLA 463 Hospital, Shenyang 110042, Liaoning Province, China

Received: 2012-04-14
Accepted: 2012-07-02
(N20120806005/MWJ)

Yang XF. Stem cell transplantation for treating Duchenne muscular dystrophy: A Web of Science-based literature analysis. Neural Regen Res. 2012;7(22):1744-1751.

www.crter.cn
www.nrronline.org

doi:10.3969/j.issn.1673-5374.2012.22.010

INTRODUCTION

Duchenne muscular dystrophy is an inherited myopathy involving skeletal muscle and myocardium, and is the commonest neurogenetic disorder[1-2]. Duchenne muscular dystrophy is a neuromuscular, X-linked recessive condition, in which mutation of the dystrophin gene leads to complete or partial lack of dystrophin protein on the myolemma[3]. Becker muscular dystrophy differs from Duchenne muscular dystrophy because of different spatial structural changes and functional incapacitation of the dystrophin protein. Duchenne muscular dystrophy is a serious condition with a poor prognosis, while Becker muscular dystrophy is a milder condition and has a more favorable prognosis[4-5].

Duchenne muscular dystrophy is known to result from a lack of dystrophin in the muscle. Dystrophin is a cytoskeletal protein expressed on the surface of the endochylema of the sarcolemma in skeletal muscle, cardiac muscle, smooth muscle and brain[6]. Dystrophin protein is encoded by a gene located on chromosome Xp2l. The dystrophin gene is one of the largest known genes, containing 79 exons. About 60% of dystrophin gene mutations are deletions, while the other 40% involve mutations other than deletions. These mutations alter the structure and function of the encoded dystrophin protein, leading to Duchenne muscular dystrophy[7].

Treatments, including symptomatic, supportive, drug, physical and orthopedic treatments, can improve the patient's condition but cannot effectively prevent disease progression. However, gene therapy and stem cell transplantation are expected to become effective treatments for patients with Duchenne muscular dystrophy. Many recent studies have used stem cell transplantation to treat Duchenne muscular dystrophy in a rat model, with improvements in pathology, physiology, biochemistry, dystrophin expression and motor function[8].

Stem cell transplantation for Duchenne muscular dystrophy may involve bone marrow stromal cells, hematopoietic stem cells, or muscle stem cells. Myofibers are polynucleated megacells without the capacity to differentiate, while normal stem cells contains the normal dystrophin gene, and can further differentiate into osteoblasts, cartilage cells, adipose cells and even sarcoblasts in the appropriate nutritive media. The aim of stem cell transplantation is to generate functional dystrophin protein.

In this study, we analyzed the research trends in stem cell transplantation for treating Duchenne muscular dystrophy, based on a bibliometric analysis of papers in Web of Science from 2002 to 2011[2].

DATA SOURCES AND METHODOLOGY

Data retrieval

This study used bibliometric analyses to quantitatively and qualitatively investigate research trends in studies of stem cell transplantation for treating Duchenne muscular dystrophy. We searched Web of Science, a research database of publications and citations selected and evaluated by the Institute for Scientific Information in Philadelphia, PA, USA, using the key words "duchenne muscular dystrophy" "Duchenne muscular dystrophy" and "stem cell". We limited the period of publication from 2002 to 2011 and compiled a bibliography of all articles related to stem cell transplantation for Duchenne muscular dystrophy. We downloaded the data on June 1st, 2012.

Inclusion criteria

The inclusion criteria were as follows: (1) published peer-reviewed articles on the use of stem cell transplantation for treating Duchenne muscular dystrophy, including original research articles, reviews, meeting abstracts, proceedings papers, book chapters, editorial material, and news items, which were indexed in Web of Science; (2) year of publication 2002–2011; and (3) citation database was Science Citation Index Expanded.

Exclusion criteria

We excluded articles that required manual searching or telephone access, documents that were not published in the public domain, and a number of corrected papers from the total number of articles analyzed.

The outcomes of all articles referring to the use of stem cell transplantation for treating Duchenne muscular dystrophy were assessed using the following criteria. (a) Annual publication output on stem cell transplantation for Duchenne muscular dystrophy included in Web of Science from 2002 to 2011. (b) Publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 according to subject areas. (c) Publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 according to journals. (d) Publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 according to country. (e) Publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 by institution. (f) Distribution of publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 by institution in China. (g) Distribution of publications on stem cell transplantation for Duchenne

muscular dystrophy in Web of Science from 2002 to 2011 by institutions that cooperated with Chinese institutions. (h) Most-cited papers on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2006. (i) Most-cited papers on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2007 to 2011.

RESULTS

Annual publication output relating to stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 (Figure 1)

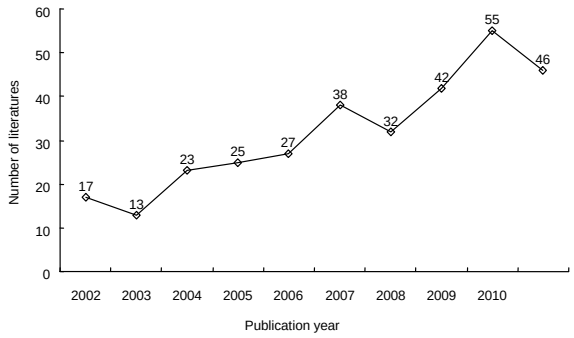


Figure 1 Annual number of publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011.

A total of 318 publications on stem cell transplantation for Duchenne muscular dystrophy were retrieved from Web of Science from 2002 to 2011. The number of relevant publications gradually increased over the 10-year study period. Seventeen papers were published and included in Web of Science in 2002, but the number of published papers had increased to 55 in 2010. However, there were slight decreases in the numbers of papers published in 2003, 2008 and 2011.

Distribution of subject areas in publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 (Table 1)

As shown in Table 1, among the subject categories related to stem cell transplantation for Duchenne muscular dystrophy from 2002 to 2011, most studies (105 papers) were in the field of cell biology, which accounted for 33.019%. The second-highest number of studies (86 papers, 27.044%) was in the field of research/experimental medicine. And in the field of biotechnology/applied microbiology, genetics/heredity and biochemistry/molecular biology, more than 50 papers on stem cell transplantation for Duchenne muscular dystrophy were published.

Table 1 Top 10 subject areas for publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011

Subject area	No. of papers	% of total publications
Cell biology	105	33.019
Research/experimental medicine	86	27.044
Biotechnology/applied microbiology	65	20.44
Genetics/heredity	58	18.239
Biochemistry/molecular biology	53	16.667
Neurosciences/neurology	31	9.748
Life sciences/biomedicine/other topics	24	7.547
Hematology	17	5.346
Transplantation	16	5.031
Oncology	14	4.403

Distribution of output according to journal for publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 (Table 2)

Table 2 Top 10 journals selected on the basis of number of publications on stem cell transplantation for Duchenne muscular dystrophy between 2002 and 2011

Journal	ISSN	Impact factor	Country	No. of papers
Molecular Therapy	1525-0016	6.873	USA	21
Neuromuscular Disorders	0960-8966	2.797	USA	12
PLoS One	1932-6203	4.092	USA	10
Human Gene Therapy	1043-0342	4.218	USA	8
Gene Therapy	0969-7128	3.710	UK	7
Human Molecular Genetics	0964-6906	7.636	UK	7
Journal of Clinical Investigation	0021-9738	13.069	USA	7
Muscle & Nerve	0148-639X	2.367	USA	7
Stem Cells	1066-5099	7.781	USA	7
Expert Opinion on Biological Therapy	1471-2598	3.505	UK	6

As shown in Table 2, *Molecular Therapy* published 21 papers, followed by *Neuromuscular Disorders*, *PLoS One* and *Human Gene Therapy*, which published 12, 10 and 8 papers, respectively. The other six top journals are *Gene Therapy, Human Molecular Genetics, Journal of Clinical Investigation, Muscle & Nerve, Stem Cells* and *Expert Opinion on Biological Therapy.*

Of the top 10 journals, seven journals were from the USA and another three journals were from the UK.

Molecular Therapy is the monthly publication of the American Society of Gene Therapy. The publisher is Nature Publishing Group in USA. It publishes 230 papers in 12 issues per year.

Neuromuscular Disorders is an international, multidisciplinary journal, which covers all aspects of neuromuscular disorders. The publisher is Pergamon-Elsevier Science ltd in USA. It publishes 78 papers in 12 issues per year.

PLoS One is published by the Public Library of Science (PLoS), a nonprofit organization in USA. It publishes 13 781 papers per year.
Human Gene Therapy is a journal covering all aspects of human gene therapy. The publisher is Mary Ann Liebert inc in USA. It publishes 145 papers in 18 issues per year.

Distribution of output according to country and institution for publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 (Figures 2, 3)
The analysis of the contributions of different countries/states to publications was based on journal articles in which the address and affiliation of at least one author were provided. A total of 318 articles were analyzed according to country and institution.

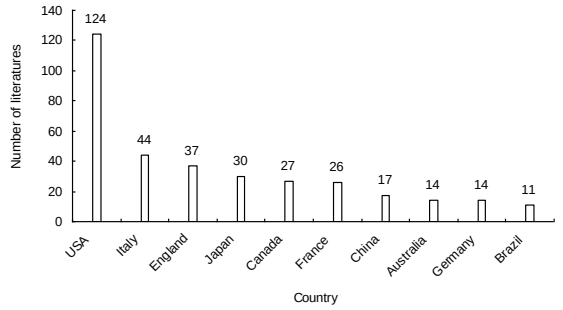
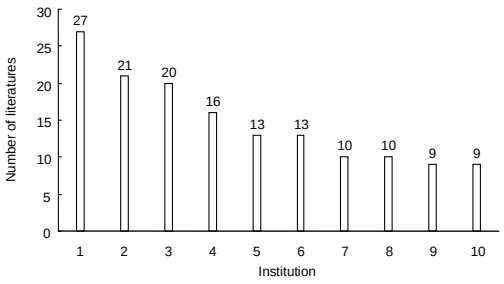


Figure 2 The top 10 countries publishing papers on stem cell transplantation for Duchenne muscular dystrophy from 2002 to 2011.



1: University of Pittsburgh, USA; 2: University of Milan, Italy; 3: University of Washington, USA; 4: Children's Hospital of Pittsburgh, USA; 5: Children's Hospital, Boston, USA; 6: Harvard University, USA; 7: University of Pavia, Italy; 8: University of Western Australia, Australia; 9: French National Center for Scientific Research, France; 10: Laval University, Canada.

Figure 3 The top 10 institutes publishing papers on stem cell transplantation for Duchenne muscular dystrophy from 2002 to 2011.

From Figure 2, it is clear that most papers on stem cell transplantation for Duchenne muscular dystrophy were published in the USA (124 papers), followed by Italy (44 papers) and the UK (37 papers). China published 17 papers, ranking 7th. The other prolific countries are Japan, Canada, France, Australia, Germany and Brazil.
From Figure 3, the University of Pittsburgh, University of Milan and University of Washington were the most prolific research institutes. Five of the top 10 research institutes publishing in this field were in the USA, two were in Italy, and one institute each was in Australia, Canada and France.

Distribution according to institutions in China for publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 (Table 3)
As shown in Table 3, Sun Yat-Sen University was the most prolific research institute in China regarding the publication of papers on stem cells transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011. Sun Yat-Sen University published seven papers.
But we found that the number of papers published by Chinese institutions was still very few.

Table 3 The top 10 Chinese institutes publishing papers on stem cell transplantation for Duchenne muscular dystrophy from 2002 to 2011

Institution	No. of papers	% of Chinese publications
Sun Yat-Sen University	7	35.294
Sichuan University	3	17.647
Mudanjiang Medical College	2	11.765
Zhejiang University	2	11.765
Chinese Academy of Medical Sciences	1	5.882
Chinese PLA 463 Hospital	1	5.882
Fourth Military Medical University	1	5.882
Guizhou Provincial Hospital	1	5.882
Luzhou Medical College	1	5.882
Peking Union Medical College	1	5.882
Shenzhen Second People's Hospital	1	5.882
Southern Medical University	1	5.882
Tongji University	1	5.882
Yangtze University	1	5.882

Distribution according to overseas institutions that cooperated with Chinese institutions for publications on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011
As shown in Table 4, most institutions that cooperated with Chinese institutions on stem cells transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2011 were from Japan and Germany. The National Institute of Child Health and Human Development in Japan published two papers after cooperated with Chinese institutions. However, the international cooperation with China in the field of stem cell transplantation for Duchenne muscular dystrophy has been rare to date.

Highly-cited papers on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2002 to 2006 (Table 5)

Table 4 The top 10 overseas institutions that cooperated with Chinese institutions regarding publications on stem cell transplantation for Duchenne muscular dystrophy from 2002 to 2011

Institution	Country	No. of papers
National Institute of Child Health and Human Development	Japan	2
International Medical Center of Japan	Japan	1
Kanazawa University	Japan	1
Keio University	Japan	1
National Cancer Center	Japan	1
Orthopedic Surgery, Straubing	Germany	1
St. Joseph's Hospital	Germany	1
University of Bonn	Germany	1
Queen's University Belfast	UK	1
University of Ljubljana	Slovenia	1
University of Trieste	Italy	1

A total of 105 papers on stem cell transplantation for Duchenne muscular dystrophy were cited in Web of Science from 2002 to 2006. Most of the 15 most-cited papers were about different kinds of stem cell transplantation for muscle regeneration. The stem cells used were muscle stem cells, mesoangioblast stem cells, mesenchymal stem cells, adipose-derived stem cells, hematopoietic stem cell, and embryonic stem cells. Most of the studies were based on animal experiments. The paper “Cellular and molecular regulation of muscle regeneration”[9] published in 2004 was cited 696 times, which was more times than any other paper. It was published by the journal *Physiological Reviews.*

Of the 15 most-cited papers, two were published in *Journal of Cell Biology,* another two were published in *Journal of Clinical Investigation*, and the remaining 11 were published in 11 different journals.

Of the 15 most-cited papers, there were five published in 2004. In 2002 and 2005, there were three top-cited papers published. And in 2003 and 2006, there was two top-cited papers published.

Highly-cited papers on stem cell transplantation for Duchenne muscular dystrophy in Web of Science from 2007 to 2011 (Table 6)

Table 5 The top 10 highly-cited papers on stem cell transplantation for Duchenne muscular dystrophy from 2002 to 2006

Title	Author	Journal	Publication year	Total citations	Average per year
Cellular and molecular regulation of muscle regeneration[9]	Chargé SB, Rudnicki MA.	Physiological Reviews	2004	696	77.33
Identification of a novel population of muscle stem cells in mice: potential for muscle regeneration[10]	Qu-Petersen Z, Deasy B, Jankowski R, *et al*	Journal of Cell Biology	2002	403	36.64
Mesoangioblast stem cells ameliorate muscle function in dystrophic dogs[11]	Sampaolesi M, Blot S, D'Antona G, *et al*	Nature	2006	246	35.14
Skeletal muscle repair by adult human mesenchymal stem cells from synovial membrane[12]	De Bari C, Dell'Accio F, Vandenabeele F, *et al*	Journal of Cell Biology	2003	180	18.00
Transplantation of a multipotent cell population from human adipose tissue induces dystrophin expression in the immunocompetent mdx mouse[13]	Rodriguez AM, Pisani D, Dechesne CA, *et al*	Journal of Experimental Medicine	2005	160	20.00
Human circulating AC133(+) stem cells restore dystrophin expression and ameliorate function in dystrophic skeletal muscle[14]	Torrente Y, Belicchi M, Sampaolesi M, *et al*	Journal of Clinical Investigation	2004	158	17.56
Muscle stem cells in development, regeneration, and disease[15]	Shi X, Garry DJ.	Genes & Development	2006	125	17.86
Long-term persistence of donor nuclei in a Duchenne muscular dystrophy patient receiving bone marrow transplantation[16]	Gussoni E, Bennett RR, Muskiewicz KR, *et al*	Journal of Clinical Investigation	2002	106	9.64
Human embryonic stem cell lines with genetic disorders[17]	Verlinsky Y, Strelchenko N, Kukharenko V, *et al*	Reproductive Biomedicine Online	2005	96	12.00
Skeletal muscle tissue engineering[18]	Bach AD, Beier JP, Stern-Staeter J, *et al*	Journal of Cellular and Molecular Medicine	2004	83	9.22
Systemic delivery of human microdystrophin to regenerating mouse dystrophic muscle by muscle progenitor cells[19]	Bachrach E, Li S, Perez AL, *et al*	Proceedings of the National Academy of Sciences of the United States of America	2004	74	8.22
Duchenne muscular dystrophy and dystrophin: pathogenesis and opportunities for treatment - third in molecular medicine review series[20]	Nowak KJ, Davies KE.	Embo Reports	2004	70	7.78
Long-term self-renewal of postnatal muscle-derived stem cells[21]	Deasy BM, Gharaibeh BM, Pollett JB, *et al*	Molecular Biology of the Cell	2005	67	8.38
The role of CD34 expression and cellular fusion in the regeneration capacity of myogenic progenitor cells[22]	Jankowski RJ, Deasy BM, Cao B, *et al*	Journal of Cell Science	2002	59	5.36
Myoblast transplantation: the current status of a potential therapeutic tool for myopathies[23]	Skuk D, Tremblay JP.	Journal of Muscle Research and Cell Motility	2003	55	5.50

Table 6 The top 10 highly-cited papers on stem cell transplantation for Duchenne muscular dystrophy from 2007 to 2011

Title	Authors	Journal	Publication year	Total citations	Average citations per year
Disease-specific induced pluripotent stem cells[24]	Park IH, Arora N, Huo H, *et al*	Cell	2008	563	112.60
Stem and progenitor cells in skeletal muscle development, maintenance, and therapy[25]	Peault B, Rudnicki M, Torrente Y, *et al*	Molecular Therapy	2007	206	34.33
Interplay of IKK/NF-kappa B signaling in macrophages and myofibers promotes muscle degeneration in Duchenne muscular dystrophy[26]	Acharyya S, Villalta SA, Bakkar N, *et al*	Journal of Clinical Investigation	2007	118	19.67
Highly efficient, functional engraftment of skeletal muscle stem cells in dystrophic muscles[27]	Cerletti M, Jurga S, Witczak CA, *et al*	Cell	2008	108	21.60
New therapies for Duchenne muscular dystrophy: challenges, prospects and clinical trials[28]	Cossu G, Sampaolesi M	Trends in Molecular Medicine	2007	67	11.17
Immunity to adeno-associated virus-mediated gene transfer in a random-bred canine model of Duchenne muscular dystrophy[29]	Wang Z, Allen, JM, Riddell SR, *et al*	Human Gene Therapy	2007	66	11.00
Autologous transplantation of muscle-derived CD133(+) stem cells in Duchenne muscle patients[30]	Torrente Y, Belicchi M, Marchesi C, *et al*	Cell Transplantation	2007	65	10.83
Repairing skeletal muscle: regenerative potential of skeletal muscle stem cells[31]	Tedesco FS, Dellavalle A, Diaz-Manera J, *et al*	Journal of Clinical Investigation	2010	62	20.67
Restoration of human dystrophin following transplantation of exon-skipping-engineered DMD patient stem cells into dystrophic mice[32]	Benchaouir R, Meregalli M, Farini A, *et al*	Cell Stem Cell	2007	60	10.00
Nitric oxide release combined with nonsteroidal anti inflammatory activity prevents muscular dystrophy pathology and enhances stem cell therapy[33]	Brunelli S, Sciorati C, D'Antona G, *et al*	Proceedings of the National Academy of Sciences of the United States of America	2007	59	9.83
Isolation of a slowly adhering cell fraction containing stem cells from murine skeletal muscle by the preplate technique[34]	Gharaibeh B, Lu A, Tebbets J, *et al*	Nature Protocols	2008	50	10.00
Complete genetic correction of IPS cells from Duchenne Muscular Dystrophy[35]	Kazuki Y, Hiratsuka M, Takiguchi M, *et al*	Molecular Therapy	2010	47	15.67
Widespread distribution and muscle differentiation of human fetal mesenchymal cells after intrauterine transplantation in dystrophic mdx mouse[36]	Chan J, Waddington SN, O'Donoghue K, *et al*	Stem Cells	2007	36	6.00
Modeling human muscle disease in zebrafish[37]	Guyon JR, Steffen LS, Howell MH, *et al*	Biochimica ET Biophysica Acta-Molecular Basis of Disease	2007	34	5.67
Regulatory factors and cell populations involved in skeletal muscle regeneration[38]	Ten Broek RW, Grefte S, Von den Hoff JW.	Journal of Cellular Physiology	2010	33	11.00

A total of 213 papers on stem cell transplantation for Duchenne muscular dystrophy were cited in Web of Science from 2007 to 2011. Most of the 15 most-cited papers were about new techniques of stem cell transplantation for treating Duchenne muscular dystrophy. The paper “Disease-specific induced pluripotent stem cells”[24] published in 2008 was cited 563 times, which was more times than any other paper. It was published by the journal *Cell.*

Of the 15 most-cited papers, two were published in *Cell,* two were published in *Molecular Therapy,* another two were published in *Journal of Clinical Investigation*, and the remaining nine papers were published in nine different journals.

Of the 15 most-cited papers, nine were published in 2007. In 2008, there were three top-cited papers published. And in 2010, there was three top-cited papers published too.

DISCUSSION

This bibliometric analysis based on Web of Science identified several research trends in studies of stem cell transplantation for Duchenne muscular dystrophy over the past 10 years. Of the 318 publications retrieved from Web of Science from 2002 to 2011, almost half derived from American authors and institutes. The number of publications gradually increased over the 10-year study period. Most papers appeared in journals with a focus on gene and molecular research, such as *Molecular Therapy*, *Neuromuscular Disorders*, and *PLoS One*. From 2002 to 2006, the 10 most-cited papers were mostly about different kinds of stem cell transplantation for muscle regeneration, while from 2007 to 2011, the 10

most-cited papers were mostly about new techniques of stem cell transplantation for Duchenne muscular dystrophy.

It must be remembered that that technology relating to stem cell transplantation for treating Duchenne muscular dystrophy is still immature. While the aim of stem cell transplantation is to generate functional dystrophin protein, Duchenne muscular dystrophy patients lack dystrophin before treatment, and normal dystrophin generated after treatment may thus be recognized by the immune system and cause immune responses[39-41]. Nonetheless, stem cell therapy represents a ground-breaking treatment that could provide an effective clinical treatment for patients with Duchenne muscular dystrophy, if the relevant technologies can be improved. The technologies required for the cultivation, purification and isolation of embryonic stem cells are gradually maturing, and because the transplanted cells do not get rejected by the recipient's immune system, no immunosuppressive agents are necessary[42]. However, the ability of this technique to increase dystrophin gene expression and thus improve muscle function remains to be determined, and considerable research is still required. Gradual improvements in the antenatal diagnosis of Duchenne muscular dystrophy can also reduce the chance of giving birth to affected individuals, and may thus further increase the opportunities for eradicating the occurrence of Duchenne muscular dystrophy.

Funding: The project was supported by the Key Technologies R & D Program of Liaoning Province, No. 2008225009.

Author contributions: Xiaofeng Yang retrieved the references, extracted the data, conceived and designed the study, and wrote the manuscript.

Conflicts of interest: None declared.

REFERENCES

[1] Chakkalakal JV, Thompson J, Parks RJ, et al. Molecular, cellular, and pharmacological therapies for Duchenne/Becker muscular dystrophies. FASEB J. 2005;19(8):880-891.

[2] Skuk D, Goulet M, Roy B, et al. Efficacy of myoblast transplantation in nonhuman primates following simple intramuscular cell injections: Toward defining strategies applicable to humans. Exp Neurol. 2002;175(1):112-126.

[3] Quenneville SP, Chapdelaine P, Rousseau J, et al. Nucleofection of muscle-derived stem cells and myoblasts with phi C31 integrase: Stable expression of a full-length-dystrophin fusion gene by human myoblasts. Mol Ther. 2004;10(4):679-687.

[4] Erickson RP. Somatic gene mutation and human disease other than cancer. Mutat Res. 2003;543(2):125-136

[5] Gussoni E, Blau HM, Kunkel LM. The fate of individual myoblasts after transplantation into muscles of DMD patients. Nat Med. 1997;3(9):970-977.

[6] Huard J, Yokoyama T, Pruchnic R, et al. Muscle-derived cell-mediated ex vivo gene therapy for urological dysfunction. Gene Ther. 2002;9(23):1617-1626.

[7] Anderson JE. The satellite cell as a companion in skeletal muscle plasticity: currency, conveyance, clue, connector and colander. J Exp Biol. 2006;209(Pt 12):2276-2292.

[8] Banks GB, Chamberlain JS. The value of mammalian models for duchenne muscular dystrophy in developing therapeutic strategies. Curr Top Dev Biol. 2008;84: 431-453.

[9] Chargé SB, Rudnicki MA. Cellular and molecular regulation of muscle regeneration. Physiol Rev. 2004; 84(1):209-238.

[10] Qu-Petersen Z, Deasy B, Jankowski R, et al. Identification of a novel population of muscle stem cells in mice: potential for muscle regeneration. J Cell Biol. 2002;157(5): 851-864.

[11] Sampaolesi M, Blot S, D'Antona G, et al. Mesoangioblast stem cells ameliorate muscle function in dystrophic dogs. Nature. 2006;444(7119):574-579.

[12] De Bari C, Dell'Accio F, Vandenabeele F, et al. Skeletal muscle repair by adult human mesenchymal stem cells from synovial membrane. J Cell Biol. 2003;160(6): 909-918.

[13] Rodriguez AM, Pisani D, Dechesne CA, et al. Transplantation of a multipotent cell population from human adipose tissue induces dystrophin expression in the immunocompetent mdx mouse. J Exp Med. 2005; 201(9):1397-1405.

[14] Torrente Y, Belicchi M, Sampaolesi M, et al. Human circulating AC133(+) stem cells restore dystrophin expression and ameliorate function in dystrophic skeletal muscle. J Clin Invest. 2004;114(2):182-195.

[15] Shi X, Garry DJ. Muscle stem cells in development, regeneration, and disease. Genes Dev. 2006;20(13): 1692-1708.

[16] Gussoni E, Bennett RR, Muskiewicz KR, et al. Long-term persistence of donor nuclei in a Duchenne muscular dystrophy patient receiving bone marrow transplantation. J Clin Invest. 2002;110(6):807-814.

[17] Verlinsky Y, Strelchenko N, Kukharenko V, et al. Human embryonic stem cell lines with genetic disorders. Reprod Biomed Online. 2005;10(1):105-110.

[18] Bach AD, Beier JP, Stern-Staeter J, et al. Skeletal muscle tissue engineering. J Cell Mol Med. 2004;8(4):413-422.

[19] Bachrach E, Li S, Perez AL. Systemic delivery of human microdystrophin to regenerating mouse dystrophic muscle by muscle progenitor cells. Proc Natl Acad Sci U S A. 2004;101(10):3581-3586.

[20] Nowak KJ, Davies KE. Duchenne muscular dystrophy and dystrophin: pathogenesis and opportunities for treatment - Third in Molecular Medicine Review Series. EMBO Rep. 2004;5(9):872-876.

[21] Deasy BM, Gharaibeh BM, Pollett JB, et al. Long-term self-renewal of postnatal muscle-derived stem cells. Mol Biol Cell. 2005;16(7):3323-3333.
[22] Jankowski RJ, Deasy BM, Cao B, et al. The role of CD34 expression and cellular fusion in the regeneration capacity of myogenic progenitor cells. J Cell Sci. 2002;115(Pt 22): 4361-4374.
[23] Skuk D, Tremblay JP. Myoblast transplantation: the current status of a potential therapeutic tool for myopathies. J Muscle Res Cell Motil. 2003;24(4-6): 285-300.
[24] Park IH, Arora N, Huo H, et al. Disease-specific induced pluripotent stem cells. Cell. 2008;134(5):877-886.
[25] Péault B, Rudnicki M, Torrente Y, et al. Stem and progenitor cells in skeletal muscle development, maintenance, and therapy. Mol Ther. 2007;15(5):867-877.
[26] Acharyya S, Villalta SA, Bakkar N, et al. Interplay of IKK/NF-kappa B signaling in macrophages and myofibers promotes muscle degeneration in Duchenne muscular dystrophy. J Clin Invest. 2007;117(4):889-901.
[27] Cerletti M, Jurga S, Witczak CA, et al. Highly efficient, functional engraftment of skeletal muscle stem cells in dystrophic muscles. Cell. 2008;134(1):37-47.
[28] Cossu G, Sampaolesi M. New therapies for Duchenne muscular dystrophy: challenges, prospects and clinical trials. Trends Mol Med. 2007;13(12):520-526.
[29] Wang Z, Allen JM, Riddell SR, et al. Immunity to adeno-associated virus-mediated gene transfer in a random-bred canine model of Duchenne muscular dystrophy. Hum Gene Ther. 2007;18(1):18-26.
[30] Torrente Y, Belicchi M, Marchesi C, et al. Autologous transplantation of muscle-derived CD133(+) stem cells in Duchenne muscle patients. Cell Transplant. 2007;16(6): 563-577.
[31] Tedesco FS, Dellavalle A, Diaz-Manera J, et al. Repairing skeletal muscle: regenerative potential of skeletal muscle stem cells. J Clin Invest. 2010;120(1):11-19.
[32] Benchaouir R, Meregalli M, Farini A, et al. Restoration of human dystrophin following transplantation of exon-skipping-engineered DMD patient stem cells into dystrophic mice. Cell Stem Cell. 2007;1(6):646-657.
[33] Brunelli S, Sciorati C, D'Antona G, et al. Nitric oxide release combined with nonsteroidal anti inflammatory activity prevents muscular dystrophy pathology and enhances stem cell therapy. Proc Natl Acad Sci U S A. 2007;104(1):264-269.
[34] Gharaibeh B, Lu A, Tebbets J, et al. Isolation of a slowly adhering cell fraction containing stem cells from murine skeletal muscle by the preplate technique. Nat Protoc. 2008;3(9):1501-1509.
[35] Kazuki Y, Hiratsuka M, Takiguchi M, et al. Complete genetic correction of iPS cells from Duchenne Muscular Dystrophy. Mol Ther. 2010;18(2):386-393.
[36] Chan J, Waddington SN, O'Donoghue K, et al. Widespread distribution and muscle differentiation of human fetal mesenchymal cells after intrauterine transplantation in dystrophic mdx mouse. Stem Cells. 2007;25(4):875-884.
[37] Guyon JR, Steffen LS, Howell MH, et al. Modeling human muscle disease in zebrafish. Biochim Biophys Acta. 2007;1772(2):205-215.
[38] Ten Broek RW, Grefte S, Von den Hoff JW. Regulatory factors and cell populations involved in skeletal muscle regeneration. J Cell Physiol. 2010;224(1):7-16.
[39] Alexakis C, Partridge T, Bou-Gharios G. Implication of the satellite cell in dystrophic muscle fibrosis: a self-perpetuating mechanism of collagen overproduction. Am J Physiol Cell Physiol. 2007;293(2):C661-669.
[40] Vainzof M, Ayub-Guerrieri D, Onofre PC, et al. Animal models for genetic neuromuscular diseases. J Mol Neurosci. 2008;34(3):241-248.
[41] Pescatori M, Broccolini A, Minetti C, et al. Gene ex-pression profiling in the early phases of DMD: a con-stant molecular signature characterizes DMD muscle from early postnatal life throughout disease progres-sion. FASEB J. 2007;21(4):1210-1226.
[42] Ciciliot S, Schiaffino S. Regeneration of mammalian skeletal muscle: basic mechanisms and clinical im-plications. Curr Pharm Des. 2010;16(8):906-914.

(Edited by Mu WJ/Song LP)