ISSN 2220-315X (online)

World Journal of *Experimental Medicine*

World J Exp Med 2016 August 20; 6(3): 58-62

Published by Baishideng Publishing Group Inc

WJEM World Journal of Experimental Medicine

A peer-reviewed, online, open-access journal of experimental medicine

Editorial Board

2016-2019

The *World Journal of Experimental Medicine* Editorial Board consists of 376 members, representing a team of worldwide experts in experimental medicine. They are from 43 countries, including Argentina (4), Australia (9), Belgium (4), Benin (1), Brazil (4), Canada (8), China (40), Croatia (2), Czech Republic (2), Denmark (1), Egypt (2), Finland (3), France (12), Germany (13), Greece (8), Hungary (1), India (14), Iran (1), Ireland (2), Israel (6), Italy (28), Japan (25), Kuwait (1), Lebanon (1), Malaysia (3), Mexico (4), Netherlands (5), Norway (2), Portugal (2), Rwanda (1), Saudi Arabia (4), Serbia (1), Singapore (2), Slovenia (2), South Korea (26), Spain (11), Sweden (7), Switzerland (2), Turkey (10), Ukraine (1), United Arab Emirates (1), United Kingdom (13), United States (87).

EDITORS-IN-CHIEF

De-Ling Kong, *Tianjin*
Atsushi Mizoguchi, *Charlestown*
Bao-Hang Zhang, *Greenville*

GUEST EDITORIAL BOARD MEMBERS

Hui-Chiu Chang, *Kaohsiung*
Nan-Shan Chang, *Tainan*
Yu-Tang Chang, *Kaohsiung*
Kow-Tong Chen, *Tainan*
Po-Jen Cheng, *Tao-Yuan*
Bor-Luen Chiang, *Taipei*
Jiin-Haur Chuang, *Kaohsiung*
Ming-Tsuen Hsieh, *Taichung*
Chih-Ping Hsu, *Hsinchu City*
Chi-Chen Lin, *Taichung*
Shih-Chang Lin, *Taipei*
Zu-Yau Lin, *Kaohsiung*
Hung-Jen Liu, *Taichung*
Wen-Huang Peng, *Taichung*
Cheng-Ta Yang, *Taipei*

MEMBERS OF THE EDITORIAL BOARD

Argentina

Beatriz Basso, *Córdoba*
Cristina E Carnovale, *Rosario*
Angel Catala, *La Plata*
Alicia Jawerbaum, *Buenos Aires*

Australia

Vasso Apostolopoulos, *Melbourne*
Dominic J Autelitano, *Richmond*
Filip Braet, *Sydney*
Xian-Lan Cui, *Launceston*
Xiao-Jun Du, *Melbourne*
Trilochan Mukkur, *Perth*
Ernst J Wolvetang, *Brisbane*
Huiling Wu, *Sydney*
Yin Xiao, *Brisbane*

Belgium

Olivier Bruyère, *Liege*
Nathalie Cools, *Edegem*
Ole F Olesen, *Brussels*
Ghislain Opdenakker, *Leuven*

Benin

Jean-Philippe Chippaux, *Cotonou*

Brazil

Niels OS Camara, *Cidade Universitária*
Ricardo E Mendes, *Concórdia*
Robson L Puntel, *Uruguaiana*
Pedro Xavier-Elsas, *Rio de Janeiro*

Canada

Wangxue Chen, *Ottawa*
Razq Hakem, *Toronto*
Alfonso Iorio, *Hamilton*
William Jia, *Vancouver*
Xiaoyan Jiang, *Vancouver*
Xuguang Li, *Ottawa*
Liting Song, *Toronto*
Jonathan P Wong, *Main Station*

China

Yi-Hua An, *Beijing*
Hong Bu, *Chengdu*
Long Chen, *Nanjing*
Heng-Mi Cui, *Nanjing*
Jian-Xin Gao, *Shanghai*
Bo Huang, *Wuhan*
Xi Huang, *Changsha*
Chun-Yan Ji, *Jinan*
Yang-Fu Jiang, *Chengdu*
Hua-Bin Li, *Guangzhou*
Sheng Li, *Shanghai*
Jian-Kang Liu, *Xi'an*
Anthony WI Lo, *Hong Kong*
Zhuo-Zhuang Lu, *Beijing*
Parco Ming-fai Siu, *Hong Kong*
Isamu Sugawara, *Shanghai*
Lun-Quan Sun, *Changsha*
Yong-Xu Sun, *Qiqihar*
Si-Dong Xiong, *Shanghai*
Wei-Hua Yan, *Linhai*
Yue-Hui Yin, *Chongqing*
Zhi-Ren Zhang, *Chongqing*
Min Zheng, *Hangzhou*
En-Min Zhou, *Yangling*

Croatia

Maja Cigrovski-Berković, *Zagreb*

Neven Zarkovic, *Zagreb*

Czech Republic

Jan Bernardy, *Brno*
Jaroslav Mokry, *Hradec Kralove*

Denmark

Shan Gao, *Aarhus*

Egypt

Nervana SH Bayoumi, *Cairo*
Ahmad Settin, *Mansoura*

Finland

Terho J Lehtimäki, *Tamper*
Jami Mandelin, *Helsinki*
Thomas Wirth, *Kuopio*

France

Nadia Alfaidy, *Grenoble*
Abdel Aouacheria, *Pierre-Benite*
Nicolas Barnich, *Ferrand*
Philippe Bouvet, *Lyon*
Jean-Marc Cavaillon, *Paris*
Jean-Marc Egly, *Illkirch*
Guido Kroemer, *Paris*
Laurent Lescaudron, *Nantes*
Cécilia Maubaret, *Bordeaux cedex*
Patrick Midoux, *Orléans*
Alain R Thierry, *Montpellier*
Mohamed Zaiou, *Nancy*

Germany

Sorin Armeanu-Ebinger, *Tübingen*
Magali Cucchiarini, *Homburg*
Christian Doehn, *Lubeck*
Alexander Hank, *Hannover*
Benjamin J Kienast, *Hamburg*
Matthias Kohl, *Schwenningen*
Sawa Kostin, *Bad Nauheim*
Hans W Müller, *Düsseldorf*
Nikolai G Rainov, *Augsburg*
Cassian Sitaru, *Freiburg*
Hermona Soreq, *Jerusalem*
Frank Thevenod, *Witten*
Kurt S Zaenker, *Witten*

Greece

Effie K Basdra, *Athens*
Maria Dalamaga, *Athens*
Moses S Elisaf, *Ioannina*
Don M Estes, *Athens*
Theofilos M Kolettis, *Ioannina*
Anastasios K Markopoulos, *Thessaloniki*
Issidora S Papassideri, *Athens*
Ioannis A Voutsadakis, *Lausanne*

Hungary

Lacza Zsombor, *Budapest*

India

Malay Chatterjee, *Kolkata*
Amitava Chatterjee, *Kolkata*
Vijay Chauthaiwale, *Gandhinagar*
Bibhu R Das, *Mumbai*
Satya N Das, *New Delhi*
Umesh D Gupta, *Agra*
Balraj Mittal, *Lucknow*
Krishnadas Nandagopal, *Kolkata*
Mohammad Owais, *Aligarh*
Kedar D Pandey, *Izatnagar*
Syed I Rizvi, *Allahabad*
Sandhya Sitasawad, *Pune*
Shailendra K Verma, *Gwalior*
Rajesh Vijayvergiya, *Chandigarh*

Iran

Nima Rezaei, *Tehran*

Ireland

Michael C Berndt, *Dublin*
Steven G Gray, *Dublin*

Israel

Mary Bakhanashvili, *Tel Hashomer*
Elena Feinstein, *Ness Ziona*
Eran Meshorer, *Jerusalem*
Majed Odeh, *Haifa*
Gili Regev-Yochay, *Ramat-Gan*
Shimon Slavin, *Tel Aviv*

Italy

Carvalho Agostinho, *Perugia*
Mario Cruciani, *Verona*
Francesco Dieli, *Palermo*
Paolo Durando, *Genoa*
Tagliabue Elda, *Milan*
Amalia Forte, *Naples*
Franco Frati, *Perugia*
Umberto Galderisi, *Naples*
Gabriele Grassi, *Trieste*
Fabio Grizzi, *Rozzano*
Angelo A Izzo, *Naples*
Lidia Larizza, *Milano*
Angelo Martino, *Rome*
Emanuela Masini, *Florence*
Sebastiano Mercadante, *Palermo*
Alberto Migliore, *Roma*
Fortunato Morabito, *Cosenza*
Pasquale Pagliaro, *Orbassano*
Enrico Pola, *Rome*
Francesco Recchia, *Avezzano*
Domenico Ribatti, *Bari*
Carlo Riccardi, *Perugia*
Gaetano Santulli, *Naples*
Luca Steardo, *Roma*
Fabrizio Stocchi, *Rome*
Giovanni Tarantino, *Naples*
Claudio Tiribelli, *Trieste*
Vincenzo Toschi, *Milano*

Japan

Winn Aung, *Chiba*
Hiroshi Fukazawa, *Mito*
Young Hak Kim, *Kyoto*
Toshio Hattori, *Sendai*
Nakashima Hideki, *Kawasaki*
Atsushi Hosui, *Osaka*
Peng Huang, *Okayama*
Kenji Kabashima, *Kyoto*
Yosuke Kakisaka, *Sendai*
Hiroshi Kanno, *Yokohama*
Takumi Kawaguchi, *Kurume*
Nanako Kawaguchi, *Tokyo*
Masahiro Kohzuki, *Sendai*
Shigeo Koido, *Chiba*
Tomoyoshi Komiya, *Kitamoto*
Ken-ichiro Kosai, *Kagoshima*
Hiroshi Mizuno, *Tokyo*
Ryuichi Morishita, *Suita*
Hiroshi Munakata, *Osakasayama*
Toshi Nagata, *Hamamatsu*
Misa Nakamura, *Osaka*
Masaaki Takamura, *Niigata*
Masakazu Toi, *Kyoto*
Toshimasa Uemura, *Ibaraki*
Ming Zhou, *Akita*

Kuwait

Gaber Ziada, *Kuwait*

Lebanon

Hala Gali-Muhtasib, *Beirut*

Malaysia

Gam L Harn, *Penang*
Kamsiah Jaarin, *Kuala Lumpur*
H S Nagaraja, *Kuala Lumpur*

Mexico

Martha PG Arreola, *Guadalajara*

Javier Camacho, *Mexico City*
José F Munoz-Valle, *Zapopan*
Eduardo Pérez-Campos, *Oaxaca*

Netherlands

Reinoud Gosens, *Groningen*
Anya N Milne, *Utrecht*
Esmaeil Mortaz, *Utrecht*
Cornelis FM Sier, *Leiden*
Ruurd Torensma, *Nijmegen*

Norway

Kristian Gundersen, *Oslo*
Leiv Ose, *Oslo*

Portugal

Fatima Baltazar, *Braga*
Fani Sousa, *Covilhã*

Rwanda

Wondatir Nigatu, *Kigali*

Saudi Arabia

Jaffar A Al-Tawfiq, *Dhahran*
Giovanni Di Salvo, *Riyadh*
Volodymyr Dvornyk, *Riyadh*
Mostafa M El-Naggar, *Jazan*

Serbia

Lidija Radenovic, *Belgrade*

Singapore

Madhav Bhatia, Singapore
Ivy Ho, *Singapore*

Slovenia

Damjan Glavac, *Ljubljana*
Srdjan Novaković, *Ljubljana*

South Korea

Dal-Woong Choi, *Seoul*
Kang-Yell Choi, *Seoul*
Sangdun Choi, *Suwon*
Young-Hwa Chung, *Busan*
Joohun Ha, *Seoul*
Kwon-Soo Ha, *Chuncheon*
Eui-Bae Jeung, *Cheongju*
Eun-Jung Jin, *Jeonbuk*
Chang-Duk Jun, *Gwangju*
Min Hyung Jung, *Seoul*
Sung-Chul Jung, *Seoul*
Young Do Jung, *Kwangju*
Hyung-Ryong Kim, *Chonbuk*
Jae Ho Kim, *Yangsan*
Jung Mogg Kim, *Seoul*
Kyu-Won Kim, *Seoul*
Se-Kwon Kim, *Busan*
Jong-Young Kwak, *Pusan*
Jeung-Hoon Lee, *Daejeon*
Jung Weon Lee, *Seoul*
Seong-Wook Lee, *Yongin*
Soo Young Lee, *Seoul*
Do Sik Min, *Pusan*
Yunbae Pak, *Jinju*
Baik Lin Seong, *Seoul*
Soon Young Shin, *Seoul*

Spain

Salvador F Alino, *Valencia*
Isabel Andia, Zamudio *Vizcaya*
Jaime Arias, *Madrid*
Javier Arias-Diaz, *Madrid*
Vicente Felipo, *Valencia*
Navarra JA Martínez, *Pamplona*
Miguel ángel Medina, *Malaga*
Jose A Obeso, *Pamplona*
Jose Prados, *Granada*
Osta P Rosario, *Zaragoza*
Jose C Segovia, *Madrid*

Sweden

Karl O Fagerstrom, *Helsingborg*
Robert Hahn, *Sodertalje*
Susanne Jacobsson, *Örebro*
Stefan Karlsson, *Lund*
Marek J Los, *Linkoping*
Jin-Jing Pei, *Tumba*
Xiao-Feng Sun, *Linkoping*

Switzerland

Florian Bihl, *Bellinzona*
Witold Kilarski, *Lausanne*

Turkey

Ali K Adiloglu, *Ankara*
Mutay Aslan, *Antalya*
Hakan Erdem, *Ankara*
Semin M Fenkci, *Denizli*
Askin Hekimoglu, *Diyarbakir*
Suleyman S Koca, *Elazig*
Cuneyt Narin, *Konya*
Mustafa Taskesen, *Diyarbakir*
Mehmet Tokac, *Konya*
Selma Yilmazer, *Istanbul*

Ukraine

Tamara M Kuchmerovska, *Kyiv*

United Arab Emirates

Azzam A Maghazachi, *Sharjah*

United Kingdom

Charles W Archer, *Cardiff*
Dominique Bonnet, *London*
Neil Davie, *Kent*
David Gilham, *Manchester*
Paul Hamilton, *Belfast*
Simon Langdon, *Edinburgh*
Tarik Massoud, *Cambridge*
Dipak P Ramji, *Cardiff*
Cordula M Stover, *Leicester*
Olga Tura, *Edinburgh*
Mark Wareing, *Manchester*
Adam Wright, *Liverpool*
Shi-Yu Yang, *London*

United States

Anshu Agrawal, *Irvine*
Arshak R Alexanian, *Milwaukee*
Mikhail Alexeyev, *Mobile*
Robert J Amato, *Houston*
Ragheb A Assaly, *Toledo*
Laure Aurelian, *Baltimore*
Joseph M Backer, *Brookfield*
Raymond T Bartus, *San Diego*
Ajay S Behl, *Minneapolis*
Fabian Benencia, *Athens*
Arun Bhunia, *West Lafayette*
Ramireddy Bommireddy, *Tucson*
Michael Borchers, *Cincinnati*
Alexander A Bukreyev, *Galveston*
Carlos Caulin, *Houston*
Arvind Chhabra, *Farmington*
Maurizio Chiriva, *Lubbock*
Yingzi Cong, *Galveston*
Akram Da'darah, *North Grafton*
Guillaume Darrasse-Jèze, *New York*
Murat Digicaylioglu, *San Antonio*
Liu-Tao Du, *Los Angeles*
Nejat Düzgüne, *San Francisco*
Charles E Egwuagu, *Bethesda*
Lian-Chun Fan, *Indianapolis*
Bing-Liang Fang, *Houston*
Markus H Frank, *Boston*
Pramod K Giri, *Athens*
Zong-Sheng Guo, *Pittsburgh*
Diane M Harper, *Louisville*
Mohamed Hassan, *Jackson*
Kremer Heidemarie, *Miami*
Marta Herreros-Villanueva, *Rochester*
Cory M Hogaboam, *Ann Arbor*
Ji-Fan Hu, *Palo Atlo*

Mohamed I Husseiny, *Duarte*
Thomas E Ichim, *San Diego*
Miroslaw Janowski, *Baltimore*
Pedro A Jose, *Washington*
Christopher J Kemp, *Washington*
Mahin Khatam, *Philadelphia*
Hyung L Kim, *Los Angeles*
Katsuhiro Kita, *New York*
Shashidhar H Kori, *Mountain View*
Raj Kumar, *Scranton*
Paul C Kuo, *Maywood*
Antonio La Cava, *Los Angeles*
Renato V La Rocca, *Louisville*
Kin-Hing W Lau, *Loma Linda*
Peng Lee, *New* York
Xiong Li, *Bangor*
Terry Lichtor, *Wilmette*
Amy Lovett-Racke, *Columbus*
Cai Lu, *Louisville*
Sha Mi, *Cambridge*
Murielle Mimeault, *Omaha*
Rajiv R Mohan, *Columbia*
Kazuhiro Oka, *Houston*
Shaowei Ong, *Belle Mead*
Peter J Quesenberry, *Providence*
Kota V Ramana, *Galveston*
Kramer P Roger, *Dallas*
Pasquale Sansone, *New York*
Tor C Savidge, *Galveston*
W Scott Goebel, *Indianapolis*
Gudlavalleti Seshu, *Omaha*
Yu Shen, *Abbott Park*
Haval Shirwan, *Louisville*
Narayan Shivapurkar, *Washington*
Evan Y Snyder, *La Jolla*
Hua Su, *San Francisco*
Yvette Taché, *Los Angeles*
Feng Tao, *Baltimore*
Alex W Tong, *Carrollton*
Deryl Troyer, *Manhattan*
Michael Vajdy, *San Francisco*
Panagiotis J Vlachostergios, *Brooklyn*
Bing Wang, *Pittsburgh*
Min Wang, *New Haven*
Ryan Wilcox, *Rochester*
Vijay Yanamadala, *Boston*
Toshifumi Yokota, *Washington*
Hong Yu, *Miami*
Xiaoliu S Zhang, *Houston*
Pan Zheng, *Ann Arbor*

WJEM World Journal of Experimental Medicine

Contents

Quarterly Volume 6 Number 3 August 20, 2016

MINIREVIEWS

58 Selected suitable seed cell, scaffold and growth factor could maximize the repair effect using tissue engineering method in spinal cord injury

Ji WC, Zhang XW, Qiu YS

Contents

World Journal of Experimental Medicine
Volume 6 Number 3 August 20, 2016

ABOUT COVER

Editorial Board Member of *World Journal of Experimental Medicine*, Zu-Yau Lin, MD, Professor, Department of Internal Medicine, Kaohsiung Medical University Hospital, Cancer Center and Division of Hepatobiliary Medicine, Kaohsiung 807, Taiwan

AIM AND SCOPE

World Journal of Experimental Medicine (*World J Exp Med*, *WJEM*, online ISSN 2220-315X, DOI: 10.5493) is a peer-reviewed open access academic journal that aims to guide clinical practice and improve diagnostic and therapeutic skills of clinicians.

WJEM covers topics concerning clinical laboratory medicine (applied and basic research in hematology, body fluid examination, cytomorphology, genetic diagnosis of hematological disorders, thrombosis and hemostasis, and blood typing and transfusion), biochemical examination (applied and basic research in laboratory automation and information system, biochemical methodology, and biochemical diagnostics), clinical microbiology (microbiological laboratory quality control and management; microbiological specimen collection and its influencing factors; conventional, automatic or molecular detection of clinical microorganisms; monitoring of bacterial and fungal drug resistance, drug resistance mechanisms, and rational application of antibiotics; monitoring and control of nosocomial infections), immunodiagnostics (laboratory diagnosis of infectious diseases, tumor markers and their application, laboratory diagnosis of autoimmune diseases, and immunotechnology), and clinical laboratory management (laboratory quality control and management, traceability and calibration, information management system and laboratory automation, and laboratory biosafety management).

We encourage authors to submit their manuscripts to *WJEM*. We will give priority to manuscripts that are supported by major national and international foundations and those that are of great clinical significance.

INDEXING/ABSTRACTING

World Journal of Experimental Medicine is now indexed in PubMed, PubMed Central.

FLYLEAF **I-IV** Editorial Board

EDITORS FOR THIS ISSUE

Responsible Assistant Editor: *Xiang Li*
Responsible Electronic Editor: *Dan Li*
Proofing Editor-in-Chief: *Lian-Sheng Ma*
Responsible Science Editor: *Jin-Xin Kong*
Proofing Editorial Office Director: *Xiu-Xia Song*

NAME OF JOURNAL
World Journal of Experimental Medicine

ISSN
ISSN 2220-315X (online)

LAUNCH DATE
December 20, 2011

FREQUENCY
Quarterly

EDITORS-IN-CHIEF
De-Ling Kong, PhD, Professor, Institute of Molecular Biology, Nankai University, Tianjin 300071, China

Atsushi Mizoguchi, MD, PhD, Associate Professor in Pathology, Harvard Medical School, Molecular Pathology Unit, Massachusetts General Hospital, CNY149-6024, 13th Steert, Charlestown, MA 02114, United States

Bao-Hong Zhang, PhD, Assistant Professor of Biology, Department of Biology, East Carolina University, Greenville, NC 27858, United States

EDITORIAL OFFICE
Jin-Lei Wang, Director
Xiu-Xia Song, Vice Director
World Journal of Experimental Medicine
Room 903, Building D, Ocean International Center,
No. 62 Dongsihuan Zhonglu, Chaoyang District,
Beijing 100025, China
Telephone: +86-10-85381891
Fax: +86-10-85381893
E-mail: editorialoffice@wjgnet.com
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
http://www.wjgnet.com

PUBLISHER
Baishideng Publishing Group Inc
8226 Regency Drive,
Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx

PUBLICATION DATE
August 20, 2016

COPYRIGHT
© 2016 Baishideng Publishing Group Co., Limited. Articles published by this Open-Access journal are distributed under the terms of the Creative Commons Attribution Non-commercial License, which permits use, distribution, and reproduction in any medium, provided the original work is properly cited, the use is non commercial and is otherwise in compliance with the license.

SPECIAL STATEMENT
All articles published in journals owned by the Baishideng Publishing Group (BPG) represent the views and opinions of their authors, and not the views, opinions or policies of the BPG, except where otherwise explicitly indicated.

INSTRUCTIONS TO AUTHORS
http://www.wjgnet.com/bpg/gerinfo/204

ONLINE SUBMISSION
http://www.wjgnet.com/esps/

World Journal of Experimental Medicine

Submit a Manuscript: http://www.wjgnet.com/esps/
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
DOI: 10.5493/wjem.v6.i3.58

World J Exp Med 2016 August 20; 6(3): 58-62
ISSN 2220-315X (online)
© 2016 Baishideng Publishing Group Inc. All rights reserved.

MINIREVIEWS

Selected suitable seed cell, scaffold and growth factor could maximize the repair effect using tissue engineering method in spinal cord injury

Wen-Chen Ji, Xiao-Wei Zhang, Yu-Sheng Qiu

Wen-Chen Ji, Xiao-Wei Zhang, Yu-Sheng Qiu, Department of Orthopedics, the First Affiliated Hospital of Xi'an Jiaotong University, Xi'an 710061, Shaanxi Province, China

Author contributions: Ji WC designed the study and wrote the manuscript; Zhang XW guided the experiment; Qiu YS modified the grammar and guided the thesis writing.

Conflict-of-interest statement: The authors declare no conflicts of interest regarding this manuscript.

Open-Access: This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

Manuscript source: Unsolicited manuscript

Correspondence to: Wen-Chen Ji, MD, Department of Orthopedics, the First Affiliated Hospital of Xi'an Jiaotong University, No.277, Yanta west Road, Xi'an 710061, Shaanxi Province, China. jiwenchenbaoyan@163.com
Telephone: +86-29-85323935
Fax: +86-29-85323930

Received: February 15, 2016
Peer-review started: February 16, 2016
First decision: March 24, 2016
Revised: March 30, 2016
Accepted: May 31, 2016
Article in press: June 2, 2016
Published online: August 20, 2016

Abstract

Spinal cord injury usually leads to permanent disability, which could cause a huge financial problem to the patient. Up to now there is no effective method to treat this disease. The key of the treatment is to enable the damage zone axonal regeneration and luckily it could go through the damage zone; last a connection can be established with the target neurons. This study attempts to combine stem cell, material science and genetic modification technology together, by preparing two genes modified adipose-derived stem cells and inducing them into neuron direction; then by compositing them on the silk fibroin/chitosan scaffold and implanting them into the spinal cord injury model, seed cells can have features of neuron cells. At the same time, it could stably express the brain-derived neurotrophic factor and neurotrophin-3, both of which could produce synergistic effects, which have a positive effect on the recovery of spinal cord. The spinal cord scaffold bridges the broken end of the spinal cord and isolates with the surrounding environment, which could avoid a scar effect on the nerve regeneration and provide three-dimensional space for the seed cell growth, and at last we hope to provide a new treatment for spinal cord injury with the tissue engineering technique.

Key words: Tissue engineering; Seed cell; Scaffold; Growth factor; Spinal cord injury

© The Author(s) 2016. Published by Baishideng Publishing Group Inc. All rights reserved.

Core tip: Spinal cord injury is a thorny disease to doctors. Tissue engineering including three core contents-seed cells, scaffolds and growth factors - is a promising method to cure this disease. Selecting suitable factors and maximizing the repairing effect is very important. This article is a hypothesis to choose the suitable factor which hopes to build up a promising method to treat spinal cord injury.

Ji WC, Zhang XW, Qiu YS. Selected suitable seed cell, scaffold

and growth factor could maximize the repair effect using tissue engineering method in spinal cord injury. *World J Exp Med* 2016; 6(3): 58-62 Available from: URL: http://www.wjgnet.com/2220-315X/full/v6/i3/58.htm DOI: http://dx.doi.org/10.5493/wjem.v6.i3.58

INTRODUCTION

Spinal cord injury (SCI) is a thorny issue to clinic doctors and scientists, the incidence of which increases year by year[1]. In China, SCI incidence is nearly 60 people per million and in the United States there are 12000 new patients each year, with the estimated totally number of Americans living with a SCI nearly 259000[2,3]. This disease not only causes great harm to the patient mentally and physically, but also increases the economic burden on the society, so it is very important to develop novel strategies to treat SCI.

In the basic research, scientists focus their attention on the following methods[4-6]: (1) using drugs; (2) taking advantage of stem cells; (3) making use of growth factors; (4) inhibiting inflammatory responses and hypertrophic scars; (5) promoting the axon growth; and (6) using tissue engineering technology. Among these, the most important method is tissue engineering technology, including three core factors-seed cells, scaffolds and growth factors (Figure 1). Thus how to select suitable seed cells, scaffolds and growth factors is very important, which could maximize the repair effect.

HYPOTHESIS

Our hypothesis is to use the tissue engineering to repair SCI in rats. Adipose-derived stem cells (ADSCs) have the characteristic of multipotential differentiation, and under certain conditions, they could differentiate into neuron cells. Constructing lentviral vectors carried brain-derived neurophic factor (*BDNF*) and neurotrophin-3 (*NT-3*) gene independently; we used it to transfect neural cells induced by the ADSCs, and thus seed cells have the properties of neurons; and at the same time, it could stably express BDNF and NT-3. Making the silk fibroin/chitosan scaffolds (SFCS), seeded transfect cells on scaffolds, implanting the composite into a 2 mm spinal cord transection rat model and taking advantage the characteristic of double gene modified neurons, they could continuously express BDNF and NT-3, and the trait of tissue engineering is shown. We are looking forward to providing a new treatment for SCI which could reduce the disability rate and mortality of SCI, and offering a solid theoretical basis for the clinical treatment of SCI (Figure 2).

EVALUATION OF THE HYPOTHESIS

Seed cell

Seed cell is the first core factor in tissue engineering which has also restricted the development of tissue

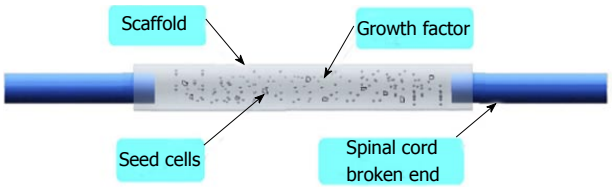

Figure 1 Scheme of using tissue engineering method to repair spinal cord injury.

engineering as a bottleneck[7]. Seed cell could be divided into non-stem cells and stem cells[8]. The former includes: Schwann cells, olfactory ensheathing cells, fibroblast, and endothelial cells; the latter is divided into two types: (1) adult stem cell: ADSCs and muscle derived stem cells (MPSCs); and (2) non-adult stem cell: Embryonic stem cell (ES), neural stem cells and bone mesenchymal stem cells (BMSCs). In the above seed cells, ES and neural stem cells have critically important usage in the basic research in the early period, but there exist some problems, such as ethical problem, reject reaction and limitation of source which could not be used widely in clinics[9]; BMSCs are widely used in basic research, but in clinical application, we need to extract the bone marrow from patients, which will cause trauma[10]. Thus more and more scientists focus their attention on the adult stem cells, which have all the above advantages and at the mean time avoid their shortcoming[11]. Although MPSCs are adult stem cells normally used in the tissue engineering, most of the experiments use them to cure heart diseases and urological diseases; and just a few studies use them to repair nerve injury; the reason is that the ability of neurogenic differentiation for MDSCs is lower than ADSCs[12-14]. So we think if we want to select a suitable adult stem cell to cure the SCI, ADSCs are better, which are first separated by Zuk *et al*[15]. Its morphology, biological characteristics and immune phenotype is similar to BMSC, and the most advanced of this stem cell is minimally invasive for the patient[16]. Thus stem cells are better than non-stem cells, and in the stem cell, adult stem cells are better than non-adult stem cells, ADSCs are the best.

Scaffold

Except for the seed cell, the scaffold is also very important, which could be divided into different types according to various standards. For example, according to the source of materials it could be divided into natural scaffold and synthetic scaffold; according to the ingredient, it could be divided into single ingredient scaffold and composite ingredient scaffold; according to different states, it could be divided into solid scaffold and liquid scaffold[17]. Compared to the single ingredient scaffold, the composite ingredient scaffold which includes several components is perhaps better, because it could avoid the disadvantage existing in the single ingredient scaffold and maximize the scaffold function[18]. In addition, compared to the synthetic scaffolds, the natural ingredients scaffold may be better, and the reason is that the immune reaction

Figure 2 Technology road mapping. SFCS: Silk fibroin/chitosan scaffolds; ADSC: Adipose-derived stem cells; NT-3-RFP: Neurotrophin-3-red fluorescent protein; BDNF: Brain-derived neurophic factor; LV-GFP: Lentivirus Green fluorescent protein.

and inflammation reaction is lighter after being implanted in the body[19].

Silk fibroin was obtained from the silk degumming and a kind of natural structural albumen was used as a scaffold in tissue engineering in many experiments. For example, Parry in their research uses silk fibroin to cure spinal fusion and finds this scaffold has a good effect[20]. But the shortcoming of this scaffold is that it is very brittle in a dry state and difficult to handle with[21]. Chitosan is another scaffold which has been researched on its biocompatibility,biodegradability, and biotoxicity for a long time, although rapid degradation and high swelling property are its problem[22]. Thus the blending of both materials to make SFCS was suggested, and the reason

is that SFCS could avoid the exclusive limitation of pure silk fibroin and chitosan, and at the mean time it has excellent mechanical properties[23]. Therefore, we think using SFCS as a scaffold to repair SCI may be a bright future direction.

Growth factor

From the above we know that seed cells and scaffolds are very important if we want to use tissue engineering technology to cure SCI, but besides them, growth factors could not be ignored, including nerve growth factors, BDNF, NT-3, glial cell line - derived neurotrophic factors and others, among which the most important are NT-3 and BDNF[24]. BDNF was extracted from porcine brain in 1982 and has a widespread effect on central neurons, which through the activation and binding of TrkB to expresses its biological effects, it could prevent neurons death and improve the pathological state of neurons after SCI[25]. *NT-3* is found in the cloning of *NGF* gene, which is a multifunctional gene and has the effect on maintaining the neuron and dopaminergic neuron differentiation[26]. Up to now, *NT-3* is considered to be the only gene which has a clear effect that could promote the corticospinal tract growth after SCI by binding and activating the TrkC to produce its biological effect[27]. Thus we want to know whether we could use BDNF and NT-3 at the same time, which may have a synergistic effect. If we want to implement this idea, we need to resolve the new challenge-how to use them, because injecting the growth factor directly may cause it to be lost and fail to take a long effect. Using gene modified technology could solve this problem. Morizono *et al*[28] did a comparison of efficiency among three kinds of viruses to transfect ADSCs and found that the highest transfection efficiency is in lentivirus. Thus lentivirus may be better, and another reason why to choose this virus carrier is that it has a main characteristic which could insert nearly 8 KB exogenous fragments and provide a possibility that connects two genes in the same carrier in the future research, and if using this transfect stem cell, gene expression may be higher than using two single genes to transfect at the same time.

CONCLUSION

If our hypothesis is confirmed, we can significantly improve the repair effect on the SCI, but we clearly know that SCI will still trouble doctors and researchers for a long time in future, and this hypothesis just provides a possibility for people in future research. If we want to successfully cure the SCI and let patients recover normally after injury, there is a long way to go. All in all, with the deepening research about tissue engineering, we think this method could be used in the clinics to cure SCI at last, which promises bright future for the patients.

REFERENCES

1 **Camune BD**. Challenges in the management of the pregnant woman with spinal cord injury. *J Perinat Neonatal Nurs* 2013; **27**: 225-231 [PMID: 23899801 DOI: 10.1097/JPN.0b013e31829ca83f]

2 **Wang M**, Zhai P, Chen X, Schreyer DJ, Sun X, Cui F. Bioengineered scaffolds for spinal cord repair. *Tissue Eng Part B Rev* 2011; **17**: 177-194 [PMID: 21338266 DOI: 10.1089/ten.TEB.2010.0648]

3 **Whitehurst DG**, Mittmann N. The value of health economics research in spinal cord injury. *Spinal Cord* 2013; **51**: 586-587 [PMID: 23907495 DOI: 10.1038/sc.2013.47]

4 **Perale G**, Rossi F, Santoro M, Peviani M, Papa S, Llupi D, Torriani P, Micotti E, Previdi S, Cervo L, Sundström E, Boccaccini AR, Masi M, Forloni G, Veglianese P. Multiple drug delivery hydrogel system for spinal cord injury repair strategies. *J Control Release* 2012; **159**: 271-280 [PMID: 22227024 DOI: 10.1016/j.jconrel.2011.12.025]

5 **Reeves A**, Keirstead HS. Stem cell based strategies for spinal cord injury repair. *Adv Exp Med Biol* 2012; **760**: 16-24 [PMID: 23281511]

6 **Kitamura K**, Fujiyoshi K, Yamane J, Toyota F, Hikishima K, Nomura T, Funakoshi H, Nakamura T, Aoki M, Toyama Y, Okano H, Nakamura M. Human hepatocyte growth factor promotes functional recovery in primates after spinal cord injury. *PLoS One* 2011; **6**: e27706 [PMID: 22140459 DOI: 10.1016/10.1371/journal.pone.0027706]

7 **Wyatt LA**, Keirstead HS. Stem cell-based treatments for spinal cord injury. *Prog Brain Res* 2012; **201**: 233-252 [PMID: 23186718 DOI: 10.1016/B978-0-444-59544-7.00012-3]

8 **Li J**, Lepski G. Cell transplantation for spinal cord injury: a systematic review. *Biomed Res Int* 2013; **2013**: 786475 [PMID: 23484157 DOI: 10.1155/2013/786475]

9 **All AH**, Bazley FA, Gupta S, Pashai N, Hu C, Pourmorteza A, Kerr C. Human embryonic stem cell-derived oligodendrocyte progenitors aid in functional recovery of sensory pathways following contusive spinal cord injury. *PLoS One* 2012; **7**: e47645 [PMID: 23091637 DOI: 10.1371/journal.pone.0047645]

10 **Ban DX**, Ning GZ, Feng SQ, Wang Y, Zhou XH, Liu Y, Chen JT. Combination of activated Schwann cells with bone mesenchymal stem cells: the best cell strategy for repair after spinal cord injury in rats. *Regen Med* 2011; **6**: 707-720 [PMID: 22050523 DOI: 10.2217/rme.11.32]

11 **Hernández J**, Torres-Espín A, Navarro X. Adult stem cell transplants for spinal cord injury repair: current state in preclinical research. *Curr Stem Cell Res Ther* 2011; **6**: 273-287 [PMID: 21476980 DOI: 10.2174/15748]

12 **Woo JC**, Bae WJ, Kim SJ, Kim SD, Sohn DW, Hong SH, Lee JY, Hwang TK, Sung YC, Kim SW. Transplantation of muscle-derived stem cells into the corpus cavernosum restores erectile function in a rat model of cavernous nerve injury. *Korean J Urol* 2011; **52**: 359-363 [PMID: 21687398 DOI: 10.4111/kju.2011.52.5.359]

13 **Shibuya M**, Miura T, Fukagawa Y, Akashi S, Oda T, Kawamura S, Ikeda Y, Matsuzaki M. Tongue muscle-derived stem cells express connexin 43 and improve cardiac remodeling and survival after myocardial infarction in mice. *Circ J* 2010; **74**: 1219-1226 [PMID: 20410616 DOI: 10.1253/circj.CJ-10-0033]

14 **Kwon EB**, Lee JY, Piao S, Kim IG, Ra JC, Lee JY. Comparison of human muscle-derived stem cells and human adipose-derived stem cells in neurogenic trans-differentiation. *Korean J Urol* 2011; **52**: 852-857 [PMID: 22216399 DOI: 10.4111/kju.2011.52.12.852]

15 **Zuk PA**. The adipose-derived stem cell: looking back and looking ahead. *Mol Biol Cell* 2010; **21**: 1783-1787 [PMID: 20375149 DOI: 10.1091/mbc.E09-07-0589]

16 **Kapur SK**, Katz AJ. Review of the adipose derived stem cell secretome. *Biochimie* 2013; **95**: 2222-2228 [PMID: 23770442 DOI: 10.1016/j.biochi.2013]

17 **Horst M**, Madduri S, Milleret V, Sulser T, Gobet R, Eberli D. A bilayered hybrid microfibrous PLGA--acellular matrix scaffold for hollow organ tissue engineering. *Biomaterials* 2013; **34**: 1537-1545 [PMID: 23177021 DOI: 10.1016/j.biomaterials.2012.10.075]

18 **Ji W**, Hu S, Zhou J, Wang G, Wang K, Zhang Y. Tissue engineering is a promising method for the repair of spinal cord injuries (Review). *Exp Ther Med* 2014; **7**: 523-528 [PMID: 24520240 DOI: 10.3892/etm.2013.1454]

19 **Ji W**, Zhang Y, Hu S, Zhang Y. Biocompatibility study of a silk fibroin-chitosan scaffold with adipose tissue-derived stem cells in

vitro. *Exp Ther Med* 2013; **6**: 513-518 [PMID: 24137218 DOI: 10.3892/etm.2013.1185]

20 **Parry PV**, Engh JA. High strength silk protein scaffolds: the future of spinal fusions. *Neurosurgery* 2012; **71**: N29-N30 [PMID: 22811208 DOI: 10.1227/01.neu.0000417541.38365.a2]

21 **Garcia-Fuentes M**, Meinel AJ, Hilbe M, Meinel L, Merkle HP. Silk fibroin/hyaluronan scaffolds for human mesenchymal stem cell culture in tissue engineering. *Biomaterials* 2009; **30**: 5068-5076 [PMID: 19564040 DOI: 10.1016/j.biomaterials.2009.06.008]

22 **Lima PA**, Resende CX, Soares GD, Anselme K, Almeida LE. Preparation, characterization and biological test of 3D-scaffolds based on chitosan, fibroin and hydroxyapatite for bone tissue engineering. *Mater Sci Eng C Mater Biol Appl* 2013; **33**: 3389-3395 [PMID: 23706225 DOI: 10.1016/j.msec.2013.04.026]

23 **Bhardwaj N**, Kundu SC. Chondrogenic differentiation of rat MSCs on porous scaffolds of silk fibroin/chitosan blends. *Biomaterials* 2012; **33**: 2848-2857 [PMID: 22261099 DOI: 10.1016/j.bio materials.2011.12]

24 **Kikuno N**, Kawamoto K, Hirata H, Vejdani K, Kawakami K, Fandel T, Nunes L, Urakami S, Shiina H, Igawa M, Tanagho E, Dahiya R. Nerve growth factor combined with vascular endothelial growth factor enhances regeneration of bladder acellular matrix graft in spinal cord injury-induced neurogenic rat bladder. *BJU Int* 2009; **103**: 1424-1428 [PMID: 18990142 DOI: 10.1111/j.1464-410X.2008.08129.x]

25 **He BL**, Ba YC, Wang XY, Liu SJ, Liu GD, Ou S, Gu YL, Pan XH, Wang TH. BDNF expression with functional improvement in transected spinal cord treated with neural stem cells in adult rats. *Neuropeptides* 2013; **47**: 1-7 [PMID: 22959240 DOI: 10.1016/j.npep.2012.06.001]

26 **Shang AJ**, Hong SQ, Xu Q, Wang HY, Yang Y, Wang ZF, Xu BN, Jiang XD, Xu RX. NT-3-secreting human umbilical cord mesenchymal stromal cell transplantation for the treatment of acute spinal cord injury in rats. *Brain Res* 2011; **1391**: 102-113 [PMID: 21420392 DOI: 10.1016/j.brainres.2011.03.019]

27 **Guo JS**, Zeng YS, Li HB, Huang WL, Liu RY, Li XB, Ding Y, Wu LZ, Cai DZ. Cotransplant of neural stem cells and NT-3 gene modified Schwann cells promote the recovery of transected spinal cord injury. *Spinal Cord* 2007; **45**: 15-24 [PMID: 16773039 DOI: 10.1038/sj.sc.3101943]

28 **Morizono K**, De Ugarte DA, Zhu M, Zuk P, Elbarbary A, Ashjian P, Benhaim P, Chen IS, Hedrick MH. Multilineage cells from adipose tissue as gene delivery vehicles. *Hum Gene Ther* 2003; **14**: 59-66 [PMID: 12573059 DOI: 10.1089/10430340360464714]

P- Reviewer: Kolettis TM, Lin ZY, Xavier-Elsas P, Zhao JB
S- Editor: Qiu S **L- Editor**: A **E- Editor**: Li D

Published by **Baishideng Publishing Group Inc**
8226 Regency Drive, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
http://www.wjgnet.com

© 2016 Baishideng Publishing Group Inc. All rights reserved.