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斑马鱼在再生医学研究中的应用及进展

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摘要 组织器官的再生现象一直以来吸引着众多生物学家们的关注。再生能力在不同物种间差异很大, 与人及高等脊椎动物相比, 低等脊椎动物(如：斑马鱼)有着较高的再生能力。斑马鱼的鳍、心脏、视网膜、视神经、脊髓、肝脏及感觉毛细胞等都具有很强的再生能力。因此, 从斑马鱼再生过程的研究中将获得大量有用的信息, 促进对人类再生能力缺陷的认识, 进而推动再生医学的发展。文章就斑马鱼在心脏、神经系统、肝脏、鳍再生医学研究中的进展及应用做一综述。

关键词： 斑马鱼 心脏再生 神经再生 肝脏再生 鳍再生

Abstract： The phenomenon of “tissue regeneration” has attracted numerous biologists for many years. Regenerative capacity differs greatly across species. The lower vertebrates such as zebrafish have exceptionally high regeneration abilities, while most high vertebrate species including humans do not have a remarkable ability for regeneration. It has been found zebrafish has a strong ability to regenerate a variety of tissues and organs including fins, heart, retina, optic nerve, spinal cord, liver, and sensory hair cells. Thus, we can learn useful information from the zebrafish regeneration model to understand the human regeneration defects and promote the development of regenerative medicine. This review summarizes the current research status for regeneration of heart, nerve, liver, and fin regeneration in zebrafish.

Keywords： zebrafish, heart regeneration, nerve regeneration, liver regeneration, fin regeneration

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[1] Poss KD. Advances in understanding tissue regenerative capacity and mechanisms in animals. Nat Rev Genet, 2010, 11(10): 710-722.

[2] Fleisch VC, Fraser B, Allison WT. Investigating regeneration and functional integration of CNS neurons: lessons from zebrafish genetics and other fish species. Biochim Biophys Acta, 2011, 1812(3): 364-380.

[3] Johnson SL, Weston JA. Temperature-sensitive mutations that cause stage-specific defects in zebrafish fin regeneration. Genetics, 1995, 141(4): 1583-1595.

[4] Poss KD, Wilson LG, Keating MT. Heart regeneration in zebrafish. Science, 2002, 298(5601): 2188-2190.

[5] Bernhardt RR, Tongiorgi E, Anzini P, Schachner M. In-creased expression of specific recognition molecules by retinal ganglion cells and by optic pathway glia accompanies the successful regeneration of retinal axons in adult zebrafish. J Comp Neurol, 1996, 376(2): 253-264. 3.0.CO;2-2 target="_blank">

[6] Becker CG, Becker T. Repellent guidance of regenerating optic axons by chondroitin sulfate glycosaminoglycans in zebrafish. J Neurosci, 2002, 22(3): 842-853.

[7] Becker CG, Lieberoth BC, Morellini F, Feldner J, Becker T, Schachner M. L1.1 is involved in spinal cord regenera-tion in adult zebrafish. J Neurosci, 2004, 24(36): 7837-7842.

[8] Sadler KC, Krahn KN, Gaur NA, Ukomadu C. Liver growth in the embryo and during liver regeneration in ze-brafish requires the cell cycle regulator, uhrf1. Proc Natl Acad Sci USA, 2007, 104(5): 1570-1575.

[9] López-Schier H, Hudspeth AJ. A two-step mechanism underlies the planar polarization of regenerating sensory hair cells. Proc Natl Acad Sci USA, 2006, 103(49): 18615-18620.

[10] Poss KD. Getting to the heart of regeneration in zebrafish. Semin Cell Dev Biol, 2007, 18(1): 36-45.

[11] Tal TL, Franzosa JA, Tanguay RL. Molecular signaling networks that choreograph epimorphic fin regeneration in zebrafish-a mini-review. Gerontology, 2010, 56(2): 231-240.

[12] Curado S, Stainier DY. deLiver'in regeneration: injury response and development. Semin Liver Dis, 2010, 30(3): 288-295.

[13] Raya A, Koth CM, Buscher D, Kawakami Y, Itoh T, Raya RM, Sternik G, Tsai HJ, Rodríguez-Esteban C, Izpisúa- Belmonte JC. Activation of Notch signaling pathway precedes heart regeneration in zebrafish. Proc Natl Acad Sci USA, 2003, 100(Suppl 1): 11889-11895.

[14] 刘新星, 张雨田, 张博. 构建斑马鱼心脏损伤-再生模型的手术方法. 遗传, 2013, 35(4): 529-532. 浏览

[15] Schnabel K, Wu CC, Kurth T, Weidinger G. Regeneration of cryoinjury induced necrotic heart lesions in zebrafish is associated with epicardial activation and cardiomyocyte proliferation. PLoS One, 2011, 6(4): e18503.

[16] Chablais F, Veit J, Rainer G, Jazwinska A. The zebrafish heart regenerates after cryoinjury-induced myocardial in-farction. BMC Dev Biol, 2011, 11: 21.

[17] Gonzalez-Rosa JM, Martin V, Peralta M, Torres M, Mercader N. Extensive scar formation and regression during heart regeneration after cryoinjury in zebrafish. Development, 2011, 138(9): 1663-1674.

[18] Wang JH, Panakova D, Kikuchi K, Holdway JE, Gember-ling M, Burris JS, Singh SP, Dickson AL, Lin YF, Sabeh MK, Werdich AA, Yelon D, Macrae CA, Poss KD. The regenerative capacity of zebrafish reverses cardiac failure caused by genetic cardiomyocyte depletion. Development, 2011, 138(16): 3421-3430.

[19] Lepilina A, Coon AN, Kikuchi K, Holdway JE, Roberts RW, Burns CG, Poss KD. A dynamic epicardial injury response supports progenitor cell activity during zebrafish heart regeneration. Cell, 2006, 127(3): 607-619.

[20] Jopling C, Sleep E, Raya M, Martí M, Raya A, Izpisua BJ. Zebrafish heart regeneration occurs by cardiomyocyte de-differentiation and proliferation. Nature, 2010, 464(7288): 606-609.

[21] Kikuchi K, Holdway JE, Werdich AA, Anderson RM, Fang Y, Egnaczyk GF, Evans T, Macrae CA, Stainier DY, Poss KD. Primary contribution to zebrafish heart regen-eration by gata4+ cardiomyocytes. Nature, 2010, 464(7288): 601-605.

[22] 孙彬, 马鹏程, 陈桂来, 王祥川, 李云. 斑马鱼心脏再生的研究. 生命的化学, 2011, 31(2): 312-316.

[23] Poss KD, Nechiporuk A, Hillam AM, Johnson SL, Keating MT. Mps1 defines a proximal blastemal proliferative compartment essential for zebrafish fin regeneration. Development, 2002, 129(22): 5141-5149.

[24] Mundt KE, Golsteyn RM, Lane HA, Nigg EA. On the regulation and function of human polo-like kinase 1 (PLK1): effects of overexpression on cell cycle progression. Biochem Biophys Res Commun, 1997, 239(2): 377-385.

[25] Petronczki M, Lénárt P, Peters JM. Polo on the rise-from mitotic entry to cytokinesis with Plk1. Dev Cell, 2008, 14(5): 646-659.

[26] Holtzinger A, Evans T. Gata4 regulates the formation of multiple organs. Development, 2005, 132(17): 4005-4014.

[27] Heicklen-Klein A, Evans T. T-box binding sites are required for activity of a cardiac GATA-4 enhancer. Dev Biol, 2004, 267(2): 490-504.

[28] Lam NT, Currie PD, Lieschke GJ, Rosenthal NA, Kaye DM. Nerve growth factor stimulates cardiac regeneration via cardiomyocyte proliferation in experimental heart failure. PLoS One, 2012, 7(12): e53210.

[29] Ikeda K, Kundu RK, Ikeda S, Kobara M, Matsubara H, Quertermous T. Glia maturation factor-γ is preferentially expressed in microvascular endothelial and inflammatory cells and modulates actin cytoskeleton reorganization. Circ Res, 2006, 99(4): 424-433.

[30] Lien CL, Schebesta M, Makino S, Weber GJ, Keating MT. Gene expression analysis of zebrafish heart regeneration. PLoS Biol, 2006, 4(8): e260.

[31] Kim J, Wu Q, Zhang Y, Wiens K M, Huang Y, Rubin N, Shimada H, Handin R I, Chao M Y, Tuan TL, Starnes VA, Lien CL. PDGF signaling is required for epicardial func-tion and blood vessel formation in regenerating zebrafish hearts. Proc Natl Acad Sci USA, 2010, 107(40): 17206-17210.

[32] Jopling C, Suñe G, Morera C, Izpisua-Belmonte JC. p38α MAPK regulates myocardial regeneration in zebrafish. Cell Cycle, 2012, 11(6): 1195-1201.

[33] Kikuchi K, Holdway JE, Major RJ, Blum N, Dahn RD, Begemann G, Poss KD. Retinoic acid production by en-docardium and epicardium is an injury response essential for zebrafish heart regeneration. Dev Cell, 2011, 20(3): 397-404.

[34] 甄一松, 惠汝太, 熊敬维. 心脏的再生性研究进展. 遗传, 2011, 33(11): 1159-1163. 浏览

[35] Porrello ER, Mahmoud AI, Simpson E, Hill JA, Richard-son JA, Olson EN, Sadek HA. Transient regenerative po-tential of the neonatal mouse

heart. Science, 2011, 331(6020): 1078-1080.

[36] Engel FB, Hsieh PC, Lee RT, Keating MT. FGF1/p38 MAP kinase inhibitor therapy induces cardiomyocyte mi-tosis, reduces scarring, and rescues function after myocar-dial infarction. Proc Natl Acad Sci USA, 2006, 103(42): 15546-15551.

[37] Becker CG, Meyer RL, Becker T. Gradients of ephrin-A2 and ephrin-A5b mRNA during retinotopic regeneration of the optic projection in adult zebrafish. J Comp Neurol, 2000, 427(3): 469-483. 3.0.CO;2-N target="_blank">

[38] Sirbulescu RF, Zupanc GK. Spinal cord repair in regen-eration-competent vertebrates: adult teleost fish as a model system. Brain Res Rev, 2011, 67(1-2): 73-93.

[39] Cameron DA, Easter SJ. Cone photoreceptor regeneration in adult fish retina: phenotypic determination and mosaic pattern formation. J Neurosci, 1995, 15(3 Pt 2): 2255-2271.

[40] Liu KS, Fetcho JR. Laser ablations reveal functional relationships of segmental hindbrain neurons in zebrafish. Neuron, 1999, 23(2): 325-335.

[41] Shahinfar S, Edward DP, Tso MO. A pathologic study of photoreceptor cell death in retinal photic injury. Curr Eye Res, 1991, 10(1): 47-59.

[42] Fimbel SM, Montgomery JE, Burket CT, Hyde DR. Re-generation of inner retinal neurons after intravitreal injec-tion of ouabain in zebrafish. J Neurosci, 2007, 27(7): 1712-1724.

[43] Sherpa T, Fimbel SM, Mallory DE, Maaswinkel H, Spritzer SD, Sand JA, Li L, Hyde DR, Stenkamp DL. Ganglion cell regeneration following whole-retina destruction in zebrafish. Dev Neurobiol, 2008, 68(2): 166-181.

[44] Curado S, Stainier DY, Anderson RM. Nitroreduc-tase-mediated cell/tissue ablation in zebrafish: a spatially and temporally controlled ablation method with applications in developmental and regeneration studies. Nat Pro-toc, 2008, 3(6): 948-954.

[45] Montgomery JE, Parsons MJ, Hyde DR. A novel model of retinal ablation demonstrates that the extent of rod cell death regulates the origin of the regenerated zebrafish rod photoreceptors. J Comp Neurol, 2010, 518(6): 800-814.

[46] Grandel H, Kaslin J, Ganz J, Wenzel I, Brand M. Neural stem cells and neurogenesis in the adult zebrafish brain: origin, proliferation dynamics, migration and cell fate. Dev Biol, 2006, 295(1): 263-277.

[47] Reichenbach A, Bringmann A. New functions of Müller cells. Glia, 2013, 61(5): 651-678.

[48] Bernardos RL, Barthel LK, Meyers JR, Raymond PA. Late-stage neuronal progenitors in the retina are radial Muller glia that function as retinal stem cells. J Neurosci, 2007, 27(26): 7028-7040.

[49] Fausett BV, Goldman D. A role for α1 tubulin-expressing Müller glia in regeneration of the injured zebrafish retina. J Neurosci, 2006, 26(23): 6303-6313.

[50] Thummel R, Kassen SC, Montgomery JE, Enright JM, Hyde DR. Inhibition of Müller glial cell division blocks regeneration of the light-damaged zebrafish retina. Dev Neurobiol, 2008, 68(3): 392-408.

[51] Becker CG, Becker T. Adult zebrafish as a model for successful central nervous system regeneration. Restor Neurol Neurosci, 2008, 26(2-3): 71-80.

[52] Qin Z, Barthel LK, Raymond PA. Genetic evidence for shared mechanisms of epimorphic regeneration in zebrafish. Proc Natl Acad Sci USA, 2009, 106(23): 9310-9315.

[53] Craig SE, Calinescu AA, Hitchcock PF. Identification of the molecular signatures integral to regenerating photore-ceptors in the retina of the zebra fish. J Ocul Biol Dis In-for, 2008, 1(2-4): 73-84.

[54] Yurco P, Cameron D A. Cellular correlates of proneural and Notch-delta gene expression in the regenerating ze-brafish retina. Vis Neurosci, 2007, 24(3): 437-443.

[55] Kassen SC, Thummel R, Campochiaro LA, Harding MJ, Bennett NA, Hyde DR. CNTF induces photoreceptor neu-roprotection and Müller glial cell proliferation through two different signaling pathways in the adult zebrafish retina. Exp Eye Res, 2009, 88(6): 1051-1064.

[56] Thummel R, Kassen SC, Enright JM, Nelson CM, Mont-gomery JE, Hyde DR. Characterization of Müller glia and neuronal progenitors during adult zebrafish retinal regen-eration. Exp Eye Res, 2008, 87(5): 433-444.

[57] Ramachandran R, Zhao XF, Goldman D. Insm1a-mediated gene repression is essential for the formation and differentiation of Müller glia-derived progenitors in the injured retina. Nat Cell Biol, 2012, 14(10): 1013-1023.

[58] Munderloh C, Solis GP, Bodrikov V, Jaeger FA, Wiechers M, Malaga-Trillo E, Stuermer CA. Reggies/flotillins regulate retinal axon regeneration in the zebrafish optic nerve and differentiation of hippocampal and N2a neurons. J Neurosci, 2009, 29(20): 6607-6615.

[59] Veldman MB, Bemben MA, Thompson RC, Goldman D. Gene expression analysis of zebrafish retinal ganglion cells during optic nerve regeneration identifies KLF6a and KLF7a as important regulators of axon regeneration. Dev Biol, 2007, 312(2): 596-612.

[60] Schweitzer J, Becker T, Becker CG, Schachner M. Expression of protein zero is increased in lesioned axon pathways in the central nervous system of adult zebrafish. Glia, 2003, 41(3): 301-317.

[61] Falk J, Bonnon C, Girault JA, Faivre-Sarrailh C. F3/contactin, a neuronal cell adhesion molecule implicated in axogenesis and myelination. Biol Cell, 2002, 94(6): 327-334.

[62] Schweitzer J, Gimnopoulos D, Lieberoth BC, Pogoda HM, Feldner J, Ebert A, Schachner M, Becker T, Becker CG. Contactin1a expression is associated with oligodendrocyte differentiation and axonal regeneration in the central nervous system of zebrafish. Mol Cell Neurosci, 2007, 35(2): 194-207.

[63] Münzel EJ, Schaefer K, Obirei B, Kremmer E, Burton EA, Kuscha V, Becker CG, Brösamle C, Williams A, Becker T. Claudin k is specifically expressed in cells that form mye-lin during development of the nervous system and regen-eration of the optic nerve in adult zebrafish. Glia, 2012, 60(2): 253-270.

[64] Kizil C, Kaslin J, Kroehne V, Brand M. Adult neurogenesis and brain regeneration in zebrafish. Dev Neurobiol, 2012, 72(3): 429-461.

[65] Kan NG, Junghans D, Izpisua-Belmonte JC. Compensatory growth mechanisms regulated by BMP and FGF signaling mediate liver regeneration in zebrafish after partial hepatectomy. FASEB J, 2009, 23(10): 3516-3525.

[66] Curado S, Anderson RM, Jungblut B, Mumm J, Schroeter E, Stainier DYR. Conditional targeted cell ablation in ze-brafish: a new tool for regeneration studies. Dev Dyn, 2007, 236(4): 1025-1035.

[67] Curado S, Ober EA, Walsh S, Cortes-Hernandez P, Verkade H, Koehler CM, Stainier DY. The mitochondrial import gene tomm22 is specifically required for hepato-cyte survival and provides a liver regeneration model. Dis Model Mech, 2010, 3(7-8): 486-495.

[68] Michalopoulos GK. Liver regeneration: alternative epithelial pathways. Int J Biochem Cell Biol, 2011, 43(2): 173-179.

[69] Dovey M, Patton EE, Bowman T, North T, Goessling W, Zhou Y, Zon LI. Topoisomerase II α is required for em-bryonic development and liver regeneration in zebrafish. Mol Cell Biol, 2009, 29(13): 3746-3753.

[70] Goessling W, North TE, Lord AM, Ceol C, Lee S, Weid-inger G, Bourque C, Strijbosch R, Haramis AP, Puder M, Clevers H, Moon RT, Zon LI. APC mutant zebrafish un-cover a changing temporal requirement for wnt signaling in liver development. Dev Biol, 2008, 320(1): 161-174.

[71] Taub R. Liver regeneration: from myth to mechanism. Nat Rev Mol Cell Biol, 2004, 5(10): 836-847.

[72] Poss KD, Shen JX, Keating MT. Induction of lef1 during zebrafish fin regeneration. Dev Dyn, 2000, 219(2): 282-286. 3.3.CO;2-3 target="_blank">

[73] Poss KD, Keating MT, Nechiporuk A. Tales of regeneration in zebrafish. Dev Dyn, 2003, 226(2): 202-210.

[74] Knopf F, Hammond C, Chekuru A, Kurth T, Hans S, Weber CW, Mahatma G, Fisher S, Brand M, Schulte-Merker S, Weidinger G. Bone regenerates via dedifferentiation of osteoblasts in the zebrafish fin. Dev Cel, 2011, 20(5): 713-724.

[75] Tu S, Johnson SL. Fate restriction in the growing and regenerating zebrafish fin. Dev Cell, 2011, 20(5): 725-732.

[76] Sousa S, Afonso N, Bensimon-Brito A, Fonseca M, Simões M, Leon J, Roehl H, Cancela ML, Jacinto A. Differentiated skeletal cells contribute to blastema formation during zebrafish fin regeneration. Development, 2011, 138(18): 3897-3905.

[77] Singh SP, Holdway JE, Poss KD. Regeneration of amputated zebrafish fin rays from de novo osteoblasts. Dev Cell, 2012, 22(4): 879-886.

[78] Stewart S, Stankunas K. Limited dedifferentiation provides replacement tissue during zebrafish fin regeneration. Dev Biol, 2012, 365(2): 339-349.

[79] Kawakami Y, Rodriguez Esteban C, Raya M, Kawakami H, Marti M, Dubova I, Izpisúa-Belmonte JC. Wnt/β-catenin signaling regulates vertebrate limb regeneration. Genes Dev, 2006, 20(23): 3232-3237.

[80] Stoick-Cooper CL, Weidinger G, Riehle KJ, Hubbert C, Major MB, Fausto N, Moon RT. Distinct Wnt signaling pathways have opposing roles in appendage regeneration. Development, 2007, 134(3): 479-489.

[81] Akimenko MA, Johnson SL, Westerfield M, Ekker M. Differential induction of four msx homeobox genes during fin development and regeneration in zebrafish. Development, 1995, 121(2): 347-357.

[82] Odelberg SJ, Kollhoff A, Keating MT. Dedifferentiation of mammalian myotubes induced by msx1. Cell, 2000, 103(7): 1099-1109.

[83] Poss KD, Shen JX, Nechiporuk A, Mcmahon G, Thisse B, Thisse C, Keating MT. Roles for Fgf signaling during ze-brafish fin regeneration. Dev Biol, 2000, 222(2): 347-358.

[84] Whitehead GG, Makino S, Lien CL, Keating MT. fgf20 is essential for initiating zebrafish fin regeneration. Science, 2005, 310(5756): 1957-1960.

[85] White JA, Boffa MB, Jones B, Petkovich M. A zebrafish retinoic acid receptor expressed in the regenerating caudal fin. Development, 1994, 120(7): 1861-1872.

[86] Quint E, Smith A, Avaron F, Laforest L, Miles J, Gaffield W, Akimenko MA. Bone patterning is altered in the regenerating zebrafish caudal fin after ectopic expression of sonic hedgehog and bmp2b or exposure to cyclopamine. Proc Natl Acad Sci USA, 2002, 99(13): 8713-8718.

[87] Smith A, Avaron F, Guay D, Padhi BK, Akimenko MA. Inhibition of BMP signaling during zebrafish fin regen-eration disrupts fin growth and scleroblast differentiation and function. Dev Biol, 2006, 299(2): 438-454.

[88] Thatcher EJ, Paydar I, Anderson KK, Patton JG. Regulation of zebrafish fin regeneration by microRNAs. Proc Natl Acad Sci USA, 2008, 105 (47): 18384-18389.

[89] Yin VP, Thomson JM, Thummel R, Hyde DR, Hammond SM, Poss KD. Fgf-dependent depletion of microRNA-133 promotes appendage regeneration in zebrafish. Genes Dev, 2008, 22(6): 728-733.

[1] 彭夕洋 陈婷芳 黄婷 江志钢 吴秀山 邓云.心脏特异表达绿色荧光斑马鱼模型的建立与评估[J]. 遗传, 2013,35(4): 511-518

[2] 谢琳 房萍 林金飞 潘洪超 张帆 申延琴.成年斑马鱼脊髓损伤修复中脑*gdnf*和*nos*基因的表达[J]. 遗传, 2013,35(4): 495-501

[3] 孙永华.第一届全国斑马鱼PI大会在武汉召开[J]. 遗传, 2013,35(4): 549-0

[4] 李方方 李文庆 荆清.G蛋白偶联受体在血管发育中的作用[J]. 遗传, 2013,35(4): 459-467

[5] 王学耕 朱作言 孙永华 赵珏.鱼类核移植与重编程[J]. 遗传, 2013,35(4): 433-440

[6] 佟静媛，柳星峰，贾顺姬.Rbb4l促进TGF-β/Nodal信号转导和斑马鱼胚胎的背部发育[J]. 遗传, 2013,35(4): 477-487

[7] 刘新星 张雨田 张博.构建斑马鱼心脏损伤-再生模型的手术方法[J]. 遗传, 2013,35(4): 529-532

[8] 张春霞 刘峰.斑马鱼高分辨率整胚原位杂交实验方法与流程[J]. 遗传, 2013,35(4): 522-528

[9] 孙婷 谢翔 张剑卿 包静 汤川政 雷道希 邱菊辉 王贵学.水平回转培养对斑马鱼血管发育的影响[J]. 遗传, 2013,35(4): 502-510

[10] 李小泉，杜久林.幼年斑马鱼的视觉系统与捕食行为[J]. 遗传, 2013,35(4): 468-476

[11] 李辉辉 黄萍 董巍 朱作言 刘东.斑马鱼研究走向生物医学[J]. 遗传, 2013,35(4): 410-420

[12] 沈延 黄鹏 张博.TALEN构建与斑马鱼基因组定点突变的实验方法与流程[J]. 遗传, 2013,35(4): 533-544

[13] 徐冉冉 张从伟 曹羽 王强.缺失*mir122*抑制斑马鱼肝脏前体细胞向肝细胞分化[J]. 遗传, 2013,35(4): 488-494

[14] 李礼，罗凌飞.以斑马鱼为模式动物研究器官的发育与再生[J]. 遗传, 2013,35(4): 421-432

[15] 黄玉斌，邹苏琪，殷梧，王昆，王晗，胡兵.成年斑马鱼OKR行为学分析[J]. 遗传, 2012,34(9): 1193-1201