



Nanomedicine and advanced technologies for burns: Preventing infection and facilitating wound healing

Mirza Ali Mofazzal Jahromi^{a,b,1}, Parham Sahandi Zangabad^{c,d,e,1,1}, Seyed Masoud Moosavi Basri^{e,f,g},
Keyvan Sahandi Zangabad^{e,h,i}, Ameneh Ghamarypour^{e,j}, Amir R. Aref^k,
Mahdi Karimi^{d,l,m,n,*}, Michael R. Hamblin^{n,o,p,**}

^a Department of Advanced Medical Sciences & Technologies, School of Medicine, Jahrom University of Medical Sciences (JUMS), Jahrom, Iran

^b Research Center for Noncommunicable Diseases, School of Medicine, Jahrom University of Medical Sciences (JUMS), Jahrom, Iran

^c Research Center for Pharmaceutical Nanotechnology (RCPN), Tabriz University of Medical Science (TUOMS), Tabriz, Iran

^d Cellular and Molecular Research Center, Iran University of Medical Sciences, Tehran, Iran

^e Bio-Nano-Interfaces: Convergence of Sciences (BNICS), Universal Scientific Education and Research Network (USERN), Tehran, Iran

^f Bioenvironmental Research Center, Sharif University of Technology, Tehran, Iran

^g Civil & Environmental Engineering Department, Shahid Beheshti University, Tehran, Iran

^h Department of Polymer Engineering, Sahand University of Technology, PO Box 51335-1996, Tabriz, Iran

ⁱ Nanomedicine Research Association (NRA), Universal Scientific Education and Research Network (USERN), Tehran, Iran

^j Department of Biology, Science and Research Branch, Islamic Azad University, Tehran, Iran

^k Department of Medical Oncology, Belfer Center for Applied Cancer Science, Dana-Farber Cancer Institute, Harvard Medical School, Boston, MA 02215, USA

^l Department of Medical Nanotechnology, Faculty of Advanced Technologies in Medicine, Iran University of Medical Sciences, Tehran, Iran

^m Research Center for Science and Technology in Medicine, Tehran University of Medical Sciences, Tehran, Iran

ⁿ Wellman Center for Photomedicine, Massachusetts General Hospital, Harvard Medical School, Boston, USA

^o Department of Dermatology, Harvard Medical School, Boston, USA

^p Harvard-MIT Division of Health Sciences and Technology, Cambridge, USA

ARTICLE INFO

Article history:

Received 24 March 2017

Received in revised form 20 July 2017

Accepted 1 August 2017

Available online 4 August 2017

Keywords:

Burn wound infection

Wound healing

Topical treatment

Nanomedicine

Nanoparticles

Stem cells

ABSTRACT

According to the latest report from the World Health Organization, an estimated 265,000 deaths still occur every year as a direct result of burn injuries. A widespread range of these deaths induced by burn wound happens in low- and middle-income countries, where survivors face a lifetime of morbidity. Most of the deaths occur due to infections when a high percentage of the external regions of the body area is affected. Microbial nutrient availability, skin barrier disruption, and vascular supply destruction in burn injuries as well as systemic immunosuppression are important parameters that cause burns to be susceptible to infections. Topical antimicrobials and dressings are generally employed to inhibit burn infections followed by a burn wound therapy, because systemic antibiotics have problems in reaching the infected site, coupled with increasing microbial drug resistance. Nanotechnology has provided a range of molecular designed nanostructures (NS) that can be used in both therapeutic and diagnostic applications in burns. These NSs can be divided into organic and non-organic (such as polymeric nanoparticles (NPs) and silver NPs, respectively), and many have been designed to display multifunctional activity. The present review covers the physiology of skin, burn classification, burn wound pathogenesis, animal

Abbreviations: 2ABI, 2-Aminobenzimidazole; Ang-2, Angiopoietin = 2; ASC, Adipose-derived stem cell; ATP, Adenosine triphosphate; AuNP, Gold nanoparticles; BALO, *Bdellovibrio* and like organisms; BC, Bacterial cellulose; BLT, Blue light therapy; CNF, Carbon nanofibers; CNP, Carbon NP; CNT, Carbon nanotubes; CrHFC, Crypreserved human cultured fibroblasts; CRISPR, clustered regularly interspaced palindromic repeats; CS, Chitosan; DC, Dendritic cell; DOTAP, N-(2,3-Dioleoyloxy-1-propyl) trimethylammonium methyl sulfate; ECM, Extracellular matrix; EGF, Epidermal growth factor; EPS, Exopolysaccharide; ERK, Extracellular regulated kinase; FDA, US Food and drug administration; FGF, Fibroblast growth factor; FIR, Far infrared; GMCSF, Granulocyte macrophage colony stimulating factor; GO, Graphene oxide; GQD, Graphene quantum dots; IGF, Insulin-C12like growth factor; iPSC, Induced pluripotent stem cell; KGF, Keratinocyte growth factor; IL, Interleukin; LED, Light emitting diode; LLLT, Low-level laser (light) therapy; LPL, Low power laser; mAb, Monoclonal antibody; MNP, Magnetic NP; MRSA, Methicillin resistant *Staphylococcus aureus*; MSC, Mesenchymal stem cells; MSN, Mesoporous silica nanoparticle; NE, Nanoemulsion; NGF, Nerve growth factor; NHDF, Normal human dermal fibroblasts; NHEK, Normal human epidermal keratinocytes; NIR, Near infrared; NO, Nitric oxide; NP, Nanoparticle; NS, Nanostructure; OP-GEL, Oxidized pectin gelatin; PcrV(A), *P. aeruginosa* V(A) antigen; PDGF, Platelet-derived growth factor; PDMS, polydimethylsiloxane; PDT, Photodynamic therapy; PEG, Polyethylene glycol; PGLA, Poly-lactic-co-glycolic acid; Phyto-AuNP, Phytochemical decorated AuNP; PMN, Polymorphonuclear neutrophil; PS, Photosensitizer; Psl, Polysaccharide synthesis locus; PTT, Photothermal therapy; PVPi, Povidone iodine complex; QD, Quantum dot; rhEGF, Recombinant human EGF; ROS, Reactive oxygen species; siRNA, Small interfering RNA; SLBN, Solid lipid-based NP; SSD, Silver sulfadiazine; SWCNT, Single wall CNT; TGF, Transforming growth factor; TiO₂ NP, Titanium dioxide NP; TLR, Toll-like receptor; TNF, Tumor necrosis factor; TTSS, Type III secretion system; VEGF, Vascular endothelial growth factor.

* Correspondence to: M. Karimi, Cellular and Molecular Research Center, Iran University of Medical Sciences, Tehran, Iran.

** Correspondence to: M. R. Hamblin, Wellman Center for Photomedicine, Massachusetts General Hospital, Harvard Medical School, Boston, USA.

E-mail addresses: m_karimy2006@yahoo.com (M. Karimi), hamblin@helix.mgh.harvard.edu (M.R. Hamblin).

¹ These two authors contributed equally to this work.

Stimulus-responsive drug delivery
 Growth factors
 Gene therapy
 CRISPR
 3D printing
 Cell-Imprinting

models of burn wound infection, and various topical therapeutic approaches designed to combat infection and stimulate healing. These include biological based approaches (e.g. immune-based antimicrobial molecules, therapeutic microorganisms, antimicrobial agents, etc.), antimicrobial photo- and ultrasound-therapy, as well as nanotechnology-based wound healing approaches as a revolutionizing area. Thus, we focus on organic and non-organic NSs designed to deliver growth factors to burned skin, and scaffolds, dressings, etc. for exogenous stem cells to aid skin regeneration. Eventually, recent breakthroughs and technologies with substantial potentials in tissue regeneration and skin wound therapy (that are as the basis of burn wound therapies) are briefly taken into consideration including 3D-printing, cell-imprinted substrates, nano-architected surfaces, and novel gene-editing tools such as CRISPR-Cas.

© 2017 Elsevier B.V. All rights reserved.

Contents

1.	Introduction	35
2.	Skin structure and the burn wound healing process.	36
2.1.	Homeostasis phase	37
2.2.	Inflammatory phase	37
2.3.	Proliferation phase	37
2.4.	Remodeling phase	38
3.	Biological-based approaches for burn wound healing	38
3.1.	Immune-based antimicrobial molecules.	38
3.1.1.	Antimicrobial peptides (AMPs)	38
3.1.2.	Passive immunotherapy.	38
3.2.	Reactive oxygen species and nitric oxide generators	39
3.3.	Antimicrobial agents	39
3.3.1.	Metallic elements	39
3.3.2.	Biopolymeric agents	39
3.4.	Therapeutic microorganisms.	40
4.	Antimicrobial light and ultrasound-based wound therapy	40
4.1.	Phototherapy	40
4.2.	Shockwave and ultrasound based-therapy	41
5.	Stem cell based-burn therapy	41
6.	Nanotechnology for treatment of burn infections and wound healing.	41
6.1.	Therapy of burn wound infections using NSs with antimicrobial effects	42
6.1.1.	Organic NPs	42
6.1.2.	Inorganic NPs	43
6.2.	Nanofibers.	45
6.3.	3D-scaffolds, films and wound dressings	47
6.4.	Smart stimulus-responsive NSs for burn wounds	48
6.5.	Photothermal and photodynamic therapy for antimicrobial activity and wound healing	50
6.6.	NS-based cell therapy for wound healing	51
6.7.	NSs for growth factor delivery	51
6.8.	NSs for gene delivery	51
6.9.	Combination therapies for wound healing.	52
6.10.	New technologies in tissue regeneration and wound healing.	52
6.10.1.	Nanoscale architected and textured substrates	52
6.10.2.	Cell-imprinted substrates	53
6.10.3.	3D bio-printed scaffolds	53
6.10.4.	CRISPR-Cas9: new gene editing tool for reprogramming of stem cells.	54
7.	Animal models for burn wounds	54
7.1.	Gas flame burn model.	54
7.1.1.	Katakura burn model	54
7.2.	Burning ethanol bath burn model	54
7.2.1.	Stieritz-Holder burn model	54
7.3.	Pre-heated single metal plate/bar burn models	54
7.3.1.	Tavares burn model	54
7.3.2.	Orenstein burn model	55
7.4.	Boiling or hot water burn models	55
7.4.1.	Suzuki burn models	55
7.4.2.	Bahar burn model	55
7.4.3.	Bjornson burn model	55
7.4.4.	Mason and Walker burn model	55
7.5.	Pre-heated double brass blocks burned models	55
7.5.1.	Kaufman burn model	55
7.5.2.	Stevens burn model	55
8.	Recent clinical trial evaluations for wound healing	55
9.	Concluding remarks and perspectives	56
	Acknowledgment	56

Download English Version:

<https://daneshyari.com/en/article/8402322>

Download Persian Version:

<https://daneshyari.com/article/8402322>

[Daneshyari.com](https://daneshyari.com)