Title: Advancing modern equine medicine using gene therapy

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Currently, regenerative medicine is seen as a promising alternative to traditional therapies. Tapping into the natural ability of the body to self-restore and heal opens up great potential to treat many disorders, including those which were considered untreatable or for which current approaches do not result in adequate or timely recovery. Stem cells are often considered a "magic bullet" to boost natural regenerative potential. Indeed, these cells are capable of self renewal, thus forming a practically unlimited pool of "spare parts", turning into almost any type of adult somatic cells, replacing dying aged cells or healing injuries. Isolated and (if necessary) expanded *in vitro* or *ex vivo* these cells find more therapeutic applications. Importantly, recent advances in biomedicine suggests that the main therapeutic effects of such stem cell transplantation is not dependent on cell replacement, but rather on paracrine stimulation of regenerative potential of resident cells through cell to cell signaling, consisting of direct contact, soluble protein factors, metabolites and microvesicles. So instead of using stem cell transplantation scientists and clinicians are considering other biologically active substances, which don't contain live cells but contain, for example, growth

factors which these cells would secrete. One such approach which has already found wide spread clinical applications is platelet rich plasma, which contains high concentrations of growth factors, other cytokines or even purified recombinant protein growth factors. However, the main disadvantage of such cell-free approaches is the short half-life of transferred biologically active substances, which are rapidly degraded by body.

Gene therapy is a new rapidly evolving therapeutic tool which has the potential to provide continuous stimulation of regeneration. Basically, we are 'hacking' host cell genomes by transferring small sections of new genetic programs in the forms of recombinant DNA or RNA molecules. These nucleic acids (in the forms of either pure (naked) plasmid DNA, nano-sized complexes or viral particles) encode different recombinant genes which are then transcribed and translated by host machinery, resulting in the biosynthesis of therapeutic proteins. Thus, instead of repeated delivery of therapeutic drugs (pharmaceuticals, recombinant proteins, etc.) we teach the organism how to continuously make its own medicine. A brilliantly technological yet natural healing mechanism.

Presently most of the attention in regenerative medicine is paid towards treating human diseases. Animals, for the most part, are considered only as models for testing human drugs. Although we do see therapeutic efficiency of such treatments in many animal models, there are often differences in the composition of biopharmaceuticals because of genetic differences between humans and animals. These differences have the potential to limit efficiency of human drugs for treating animal diseases due to incomplete homology. Even more importantly, such drugs could raise immunogenicity issues, potentially having long term immunological problems, development of autoimmunity and decreased efficiency of subsequent treatments, or even negative side-effects including anaphylactic shock. When it comes to autologous (or even allogeneic) transplantation or corresponding animal cell-free products, such as platelet-rich plasma, it is not a problem. But in cases of more advanced therapeutic approaches, such as gene therapy, complete homology might be vital.

This is why we are focusing our research on developing gene therapy applications using species specific recombinant genes, which will provide full biological activity and simultaneously have

no immunological side effects. We have developed plasmid DNA gene therapy drugs, encoding horse specific genes. For example, plasmid DNA encoding equine vascular endothelial growth factor (VEGF) and fibroblast growth factor 2 (FGF2) [1] which demonstrated safety and efficiency in a recently published case report study of treating tendinitis and desmitis in horses [2]. Treatment of these conditions is a tedious task for veterinary doctors. Existing techniques using autologous or allogeneic stem cells or platelet-rich plasma injections have limited efficiency, thus making development of new strategies for tendon regeneration of great importance. The mechanisms of action of the gene therapy involving VEGF and FGF2 probably involves increased vascularization of damaged tissues, resulting in higher rate of regeneration. Both VEGF and FGF2 are well known growth factors with wide spectrum of mitogenic and angiogenic activity. They also promote regeneration of muscular and connective tissue. More importantly, in combination these growth factors demonstrate synergetic effects, which surpass effect of single growth factor therapy applications.

With gene therapy becoming such a viable option, much consideration needs to be given to not only the design and development of new therapies and applications, but also to how animals receive treatment. The need for training for both established veterinary surgeons and undergraduate students is becoming essential. Initially the regimes will be implemented by veterinary gene therapy specialists but over time these therapies will be used in clinics throughout the world. Naturally much care and consideration is also required in ensuring that all new therapies are appropriately tested and have high standards of production and regulation. In addition these treatments will need to be discussed with the international associations involved in the regulation and breeding of horses. As with any new treatment the matter of educating and informing the public, owners, health and welfare providers and veterinary professionals is of utmost importance. With so many types of gene delivery potentially available and so many more being developed and trialed, the intricacies of each treatment for differing conditions can be difficult to portray to the owner. As of December 2017, three human gene therapy drugs had been approved by the United States Food and Drug Administration [3]. With our latest successful trials and the advances in technology and genetics, the future for veterinary gene

therapy looks promising and it is likely that many more therapies will become licensed for use in both human and animal medicine.

Conflicts of interest

The authors declare no conflicts of interest.

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References

[1] Litvin, Y.A., Zakirova, E.Y., Zhuravleva, M.N. and Rizvanov, A.A. (2016) Generation of Plasmid DNA Expressing Species-Specific Horse VEGF164 and FGF2 Factors for Gene Therapy. *Bionanoscience* **6**, 550-553.

[2] Kovac, M., Litvin, Y.A., Aliev, R.O., Zakirova, E.Y., Rutland, C.S., Kiyasov, A.P. and Rizvanov, A.A. (2017) Gene Therapy Using Plasmid DNA Encoding Vascular Endothelial Growth Factor 164 and Fibroblast Growth Factor 2 Genes for the Treatment of Horse Tendinitis and Desmitis: Case Reports. *Front Vet Sci* **4**, 168.

[3] FDA. (2017) What Is Gene Therapy? How Does It Work?, U.S. Food and Drug Administration, USA.