



Corrigendum: Confused Connections? Targeting White Matter to Address Treatment Resistant Schizophrenia

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A Corrigendum on

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In the original article Palaniyappan, personal comm. was not cited in the article. The citation has now been inserted in *Pharmacological WM Targets in Treatment Resistant Schizophrenia: Human Studies*, paragraphs 1 and 11 and should read:

Paragraph one:

Based on the literature reviewed here, there are WM deficits that correlate with treatment resistance in schizophrenia. While other mechanisms of pharmacoresistance are still possible for any particular patient, if we consider WM as a target for therapy, there are options that are in development for human use. In fact, myelin enhancing strategies have been under investigation in human subjects for many years as effective treatments for multiple sclerosis are sought. Thus, repurposing and investigating these approved therapeutics currently in use for other medical conditions for treatment resistant patients is a reasonable approach. More specifically, putative myelin enhancing therapies would be potential candidates for large-scale clinical trials in schizophrenia. These include myelin-enhancing agents such as n-3 PUFA (Chen et al., 2014), minocycline (Rodgers et al., 2013), clemastine (Liu et al., 2016), polyphenols (Ghaiad et al., 2017), and potential neuro/myeloreparative agents such as sulfasalazine (Kim et al., 2015), nano-curcumin (Mohajeri et al., 2015), stem cell enhancing therapies such as Gli-1 inhibitors (Samanta et al., 2015), immunomodulators such as fingolimod [FTY720, approved for use in MS (Kipp and Amor, 2012)], olexosime (Magalon et al., 2016) and retinoid receptor activators such as pioglitazone (Natrajan et al., 2015; Palaniyappan, personal comm.) (Summarized in Figure 2 and Table 2).

Paragraph 11:

A number of these agents are suitable for drug repurposing and repositioning applications, which greatly enhances the lab-to-clinic transition (Ashburn and Thor, 2004). Repurposing RCTs are already underway for some of these agents [e.g., fingolimod (fingolimod in Schizophrenia clinicaltrials.gov)] and pioglitazone (Iranpour et al., 2016). Of these minocycline, which

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predominantly limits neuronal damage by promoting oligodendrocyte progenitor proliferation and preserving mature oligodendrocytes (Guimaraes et al., 2010; Schmitz et al., 2012; Ma et al., 2015; Scheuer et al., 2015), and pioglitazone which promotes antioxidant defense of oligodendrocytes (Bernardo et al., 2009) have already shown promise in treating psychosis (Chaudhry et al., 2012; Iranpour et al., 2016). Further

work is needed to see if an association exists between extensive WM changes and pharmacoresistance, but if it does then these individuals can be specifically targeted for clinical trials of myeloprotection (Palaniyappan, personal comm.).

The authors apologize for these errors and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

REFERENCES

- Ashburn, T. T., and Thor, K. B. (2004). Drug repositioning: identifying and developing new uses for existing drugs. *Nat. Rev. Drug Discov.* 3, 673–683. doi: 10.1038/nrd1468
- Bernardo, A., Bianchi, D., Magnaghi, V., and Minghetti, L. (2009). Peroxisome proliferator-activated receptor-gamma agonists promote differentiation and antioxidant defenses of oligodendrocyte progenitor cells. *J. Neuropathol. Exp. Neurol.* 68, 797–808. doi: 10.1097/NEN.0b013e3181a8ba2c1
- Chaudhry, I. B., Hallak, J., Husain, N., Minhas, F., Stirling, J., Richardson, P., et al. (2012). Minocycline benefits negative symptoms in early schizophrenia: a randomised double-blind placebo-controlled clinical trial in patients on standard treatment. *J. Psychopharmacol.* 26, 1185–1193. doi: 10.1177/0269881112444941
- Chen, S., Zhang, H., Pu, H., Wang, G., Li, W., Leak, R. K., et al. (2014). n-3 PUFA supplementation benefits microglial responses to myelin pathology. *Sci. Rep.* 4, 7458. doi: 10.1038/srep07458
- Ghaiaid, H. R., Nooh, M. M., El-Sawalhi, M. M., and Shaheen, A. A. (2017). Resveratrol promotes remyelination in cuprizone model of multiple sclerosis: biochemical and histological study. *Mol. Neurobiol.* 54, 3219–3229. doi: 10.1007/s12035-016-9891-5
- Guimaraes, J. S., Freire, M. A., Lima, R. R., Picanco-Diniz, C. W., Pereira, A., and Gomes-Leal, W. (2010). Minocycline treatment reduces white matter damage after excitotoxic striatal injury. *Brain Res.* 1329, 182–193. doi: 10.1016/j.brainres.2010.03.007
- Iranpour, N., Zandifar, A., Farokhnia, M., Gogul, A., Yekehtaz, H., Khodaie-Ardakani, M. R., et al. (2016). The effects of pioglitazone adjuvant therapy on negative symptoms of patients with chronic schizophrenia: a double-blind and placebo-controlled trial. *Hum. Psychopharmacol.* 31, 103–112. doi: 10.1002/hup.2517
- Kim, S., Lee, Y. I., Chang, K. Y., Lee, D. W., Cho, S. C., Ha, Y. W., et al. (2015). Promotion of remyelination by sulfasalazine in a transgenic zebrafish model of demyelination. *Mol. Cells* 38, 1013–1021. doi: 10.14348/molcells.2015.0246
- Kipp, M., and Amor, S. (2012). Fty720 on the way from the base camp to the summit of the mountain: relevance for remyelination. *Mult. Scler.* 18, 258–263. doi: 10.1177/1352458512438723
- Liu, J., Dupree, J. L., Gacias, M., Frawley, R., Sikder, T., Naik, P., et al. (2016). Clemastine enhances myelination in the prefrontal cortex and rescues behavioral changes in socially isolated mice. *J. Neurosci.* 36, 957–962. doi: 10.1523/JNEUROSCI.3608-15.2016
- Ma, J., Zhang, J., Hou, W. W., Wu, X. H., Liao, R. J., Chen, Y., et al. (2015). Early treatment of minocycline alleviates white matter and cognitive impairments after chronic cerebral hypoperfusion. *Sci. Rep.* 5:12079. doi: 10.1038/srep12079
- Magalon, K., Le Grand, M., El Waly, B., Moulis, M., Pruss, R., Bordet, T., et al. (2016). Olesoxime favors oligodendrocyte differentiation through a functional interplay between mitochondria and microtubules. *Neuropharmacology* 111, 293–303. doi: 10.1016/j.neuropharm.2016.09.009
- Mohajeri, M., Sadeghizadeh, M., Najafi, F., and Javan, M. (2015). Polymerized nano-curcumin attenuates neurological symptoms in eae model of multiple sclerosis through down regulation of inflammatory and oxidative processes and enhancing neuroprotection and myelin repair. *Neuropharmacology* 99, 156–167. doi: 10.1016/j.neuropharm.2015.07.013
- Natrajan, M. S., Komori, M., Kosa, P., Johnson, K. R., Wu, T., Franklin, R. J., et al. (2015). Pioglitazone regulates myelin phagocytosis and multiple sclerosis monocytes. *Ann Clin Transl Neurol.* 2, 1071–1084. doi: 10.1002/acn3.260
- Rodgers, J. M., Robinson, A. P., and Miller, S. D. (2013). Strategies for protecting oligodendrocytes and enhancing remyelination in multiple sclerosis. *Discov. Med.* 16, 53–63.
- Samanta, J., Grund, E. M., Silva, H. M., Lafaille, J. J., Fishell, G., and Salzer, J. L. (2015). Inhibition of Gli1 mobilizes endogenous neural stem cells for remyelination. *Nature* 526, 448–452. doi: 10.1038/nature14957
- Scheuer, T., Brockmoller, V., Blanco Knowlton, M., Weitkamp, J. H., Ruhwedel, T., Mueller, S., et al. (2015). Oligodendroglial maldevelopment in the cerebellum after postnatal hyperoxia and its prevention by minocycline. *Glia* 63, 1825–1839. doi: 10.1002/glia.22847
- Schmitz, T., Endesfelder, S., Chew, L. J., Zaak, I., and Buhner, C. (2012). Minocycline protects oligodendroglial precursor cells against injury caused by oxygen-glucose deprivation. *J. Neurosci. Res.* 90, 933–944. doi: 10.1002/jnr.22824

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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