Plasticity following surgical correction of strabismus in monkeys

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Strabismus surgery is well documented in both the literature and in practice with varying levels of success and permanence. Potentially, muscle remodeling and/or central neural adaptation affects the final state of misalignment after treatment. Our goal was to assess central adaptation by examining responses of motoneurons in the oculomotor and abducens nuclei of strabismic monkeys before and after treatment. The study included one rhesus monkey with an exotropia (divergent strabismus). Strabismus had previously been induced using an optical prism-viewing paradigm from birth until 4 months to disrupt binocular vision during their critical period for visual development. A recession/resection surgery was performed at 6 years of age to weaken the lateral rectus and strengthen the medial rectus of the left eye only. We recorded from 21 medial rectus motoneurons (MRMN) and 75 abducens neurons (ABN) prior to treatment and from 70 MRMN and 92 ABN over the first 6 months following treatment. Firing rates (FR) and horizontal eye position and velocity acquired during a monocular viewing smooth pursuit task (0.3Hz, ±15°) were used to identify regression coefficients in a first-order model ($FR = K*E_{pos} + R*E_{vel} + C$). K and C coefficients were then used to compute a population neuronal drive (ND) to each muscle necessary to produce static deviation of the covered eye before surgery (pre), <1 month after surgery (post1), ~6 months after surgery (post6). We found that strabismus angle (SA) was reduced by ~60% the day after surgery and gradually increased to settle at ~20-30% reduction over pre-surgery values at Post6. Analysis of ND to the treated (left) eye at Post1 showed that there was a significant decrease of ND to the MR and a small but not significant increase of ND to LR. Both of these neuronal adaptive changes are in fact acting to ‘counter’ the goal of the surgery. Analysis of ND to the untreated (right) eye at Post1 showed a significant increase of ND to the MR and significant decrease of ND to LR both of which are appropriate for a reduction of strabismus angle. Over the long-term, ND’s to all muscles appeared to more or less revert to pre-surgical values. By using the ND values to each muscle and the strabismus angle measurements, we were also able to estimate a contractility coefficient for each muscle. In summary, alterations in muscle strength due to surgery drives the reduction of strabismus angle immediately after surgery but this effect is somewhat diluted by neuronal adaptation that is ‘fighting’ the surgery. Over the long-term, continued neural adaptation in addition to muscle remodeling is responsible for setting the steady-state strabismus angle.