EDITORIAL

The breathing arm revisited**Vanessa J. Sammons, MBBS, MPhil, FRACS, and Rajiv Midha, MD, MSc, FRCSC**

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TRAUMATIC brachial plexus injuries (TBPIs) affect only about 1% of the trauma patient population; however, TBPI is a devastating injury for the predominantly young male patient group affected.⁵ While the degree of injuries sustained is heterogeneous, loss of any function of the arm is significant in a psychological and economic sense, with a profound effect on the individual and society.¹

Complete restoration of function is the pinnacle of what peripheral nerve surgeons want to achieve. Today, however, this is simply unachievable, especially in pan-plexus severe injuries. In these adult patients, focus is given to restoring what movement might be the most beneficial for the individual patient. The main aims in the setting of a pan-plexus injury are usually:² 1) shoulder girdle stability, 2) restoration of elbow flexion, and 3) restoration of elbow extension.

For nerve root avulsion injuries, a growing variety of nerve transfer options are available to us as surgeons and new possibilities are constantly being considered and explored. Options are determined by the anatomy of the injury and what functioning nerve donors remain. Elbow flexion is considered fundamental in the use of the arm for activities of daily living. There are several described options for nerve transfer to the musculocutaneous nerve (MCN) that include intercostal nerves (ICNs), an accessory nerve with a nerve graft, ulnar nerve fascicles, median nerve fascicles, the medial pectoral nerve, thoracodorsal nerve, and contralateral C7. When no intraplexal donors are available (severe pan-plexus injuries with multiple avulsions), one of the other main options is transfer of the ipsilateral phrenic nerve (PN) to the main MCN branch in the hope that the transplanted phrenic motor axons may continue to grow into the MCN beyond the injury to restore some muscle function (to biceps and brachialis). This transfer was first described by Gu et al. in the 1980s.³

The reported success of this nerve transfer in achiev-

ing Medical Research Council grade 4 elbow flexion is approximately 62%.⁶ While reasonably widely used, the PN-MCN transfer has not been universally adopted, in part because of concerns regarding reduced pulmonary function given the resultant hemidiaphragmatic paralysis. Indeed, it has been shown that use of a donor PN reduces pulmonary vital capacity;⁴ however, this patient cohort is generally young and fit and most studies have not found a significant detrimental effect on clinical respiratory function.⁶ The lack of a detrimental effect over the long term remains to be proven. The varying support for this nerve transfer amongst surgeons and institutions is likely shaped by experience regarding the aforementioned considerations, and also the relative success (in terms of recovery of elbow flexion) of the transfer in the experience of the institution.

There are two significant considerations: 1) potential long- and short-term consequences of paralysis of the ipsilateral hemidiaphragm after sectioning of the donor PN; and 2) the influence of breathing on arm movement (both active movement and at rest).

The PN-MCN transfer does have particular features of association with respiration; it may be expected that any subsequent motor action in the target muscles after transfer is affected by inspiration. The work by Socolovsky and colleagues in this issue of the *Journal of Neurosurgery*⁷ addresses this and presents a well-executed quantitative evaluation of the outcomes of patients who have received the PN-MCN transfer at their institution.

Briefly, the authors present a retrospective study to identify the relationship between breathing and elbow flexion in patients with severe pan-plexus TBPI who underwent PN-MCN transfer to restore elbow flexion. They were able to assess 21 patients (19 male) who underwent surgery between 2005 and 2016. The mean interval from trauma to surgery was 5.5 months, while the mean duration of follow-up was 2.6 years. The majority of the pa-

tients recovered some elbow flexion function. They found that breathing affected elbow function in this patient cohort, with increased biceps strength (by dynamometry) and greater degree of elbow flexion (by measuring angles) after inspiration compared to postexpiration. They also found that there was some waning of this effect over time, particularly in the range of motion of the elbow.

Where prior work has demonstrated the effectiveness of the technique for restoring elbow flexion, the current work extends these qualitative observations by quantitatively showing that breathing has a significant impact on the strength of elbow flexion, namely that early in recovery, deep inspiration has a significant positive impact. Indeed, even range of motion is increased with deep inspiration.

The authors raise the question of neuroplasticity in affecting return of function, i.e., that the waning described above is possibly a result of neuroplasticity. The concept of neuroplasticity is increasingly being discussed in the literature with greater understanding of the neuronal connection changes that occur, even with advancing age.⁸ It is interesting to observe neuroplasticity in the context of nerve transfers that are becoming increasingly common. By increasing our understanding of this phenomenon, we may be able to further expand our repertoire but also refine techniques and decision-making. We look forward to further work by Socolovsky and colleagues in deciphering how neuroplasticity may impact recovery from nerve transfer reconstructions and how that recovery may change with time.

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Disclosures

The authors report no conflict of interest.

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