Voluntary Neuromuscular Control of Gracilis Free Functioning Muscle Transfer for Elbow Flexion: Spinal Accessory Nerve vs Intercostal Nerve

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INTRODUCTION: Traumatic brachial plexus injuries (BPI) are common in accidents where the neck and the shoulder are forcibly displaced in opposite directions. Adult traumatic BPI has increased with rise in popularity of extreme sports, and vehicular accident survivors[1-3]. Surgical interventions such as a gracilis free functioning muscle transfer (gFFMT) are required to restore some function to the elbow and hand. The Spinal accessory nerve (SAN) and Intercostal nerves (ICN) are the common extra plexal motor donors in a gFFMT. The selection of either SAN or ICN for reinnervation is controversial with current studies considering only subjective measures of recovery[4]. Neuromuscular control is overlooked when selecting the donor nerve. Hence, there is a knowledge gap in the objective quantification of the effectiveness of the SAN versus the ICN in gFFMT. In this study, it was hypothesized that subjects reinnervated with the SAN would have better neuromuscular control in the gracilis muscle (gFFMT to the bicep) when used for elbow flexion.

METHODS: Twenty adult subjects with a gFFMT surgery following a brachial plexus injury were recruited from the Brachial Plexus Injury Clinic at the Mayo Clinic. The subjects were grouped by the donor nerve used for the gFFMT. Two subjects from the SAN group were excluded from the analysis due to technical issues during data collection. After exclusion, the SAN group (27 ± 8 years) and the ICN group (38 ± 10 years) consisted of 9 subjects each. The groups were similar in height and weight. Subjects were evaluated with a custom device that measured elbow flexion torque (TS11–20, Interface Inc.). The experimental sessions were comprised of a resting trial, a trial involving maximum voluntary contraction, and eight sequential trials of increasing difficulty. Participants were tasked with matching their elbow flexion torque to a target torque value (pre-set as a percentage of their peak torque) displayed in real-time on a digital screen (LabVIEW 2019, National Instruments Corp). Throughout the stairstep sequence, participants were confronted with the challenge of sustaining their torque output at each level for a duration of 5 seconds. The outcome measures collected were the time taken to reach the target torque (latency), and the time the target torque was held (hold time) for individual target torques[5]. The latency was then further grouped by whether the subject increased or decreased their elbow torque to reach the target torque. Since the SAN group and the ICN group were different in terms of their age and the time since surgery (TSS), the latencies and the hold time were adjusted to account for this difference. A Type 1 factorial ANOVA test was used to study the relationship between the outcome measures (adjusted latencies and hold time) and the independent variables (nerve used, percentage target torque, and their interactions). Statistical significance was defined as $p < 0.05$.

RESULTS: The SAN group performed better in all outcome measures. The adjusted contraction latency was 10 times lower in the SAN group compared to the ICN group ($p < 0.05$) (Fig. 1 a). The adjusted relaxation latency value was 7 times lower in the SAN group compared to the ISN group ($p < 0.05$). The SAN group also showed a weak amount of modulation in their adjusted relaxation latency (value decreased) as the target torque increased (Fig. 1 b). The adjusted hold time was 6 times higher in the SAN group than the ICN group ($p < 0.05$) (Fig. 1 c). Percentage target torque was not a significant factor for the outcome measures.

DISCUSSION: The results demonstrate that the SAN is a superior donor nerve for a gFFMT when motor control is desired. SAN are motor nerves that innervate the Sternocleidomastoid and Trapezius muscles, and ICN are mixed nerves responsible for both motor and sensory functions that innervate the intercostal muscles. The surgeons have more motor nerves available while using the SAN for a gFFMT. Hence, using the SAN reinnervated gracilis for motor control is more intuitional compared to ICN. Bhat et. al.'s article showed that healthy individuals modulated the latency with elbow torque demand[5]. The SAN group had a similar, but weak, ability compared to the ICN group. Oliver et. al.'s systematic review states that the success rates of gFFMT using the SAN or the ICN were similar[4]. Hence, SAN as a donor nerve is a better option for gFFMT.

CLINICAL RELEVANCE: Selection of the right nerve for a gFFMT is crucial. The SAN, when available, is the best choice for a gFFMT. The findings of this study can be used to guide surgeons performing gFFMT.

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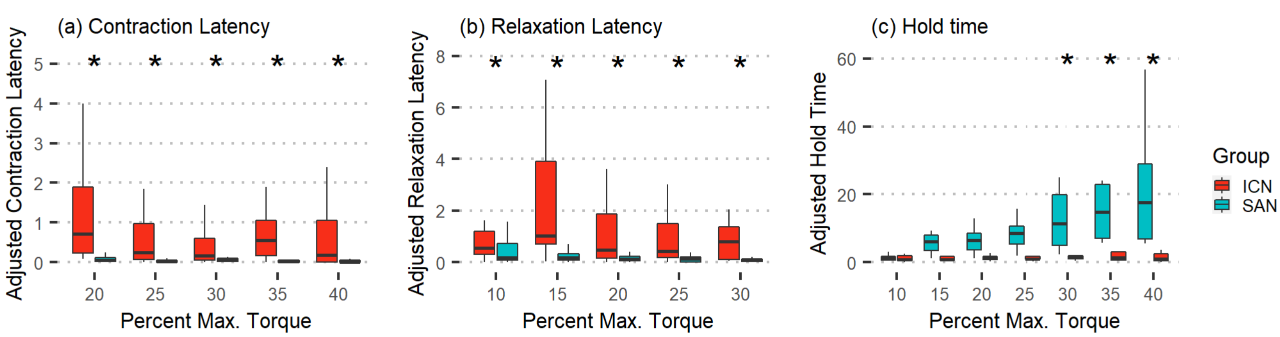

Figure 1. SAN group showed lower relaxation and contraction latency (lower is better) and higher hold time (higher is better) compared to the ICN group. (*: $p < 0.05$)