Impact of Muscle Graft Volume on Signaling Capacity in the Regenerative Peripheral Nerve Interface for Neuroprosthetic Control

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INTRODUCTION: There are over 540,000 inidivuals in the United States living with upper limb loss.[1] Regenerative Peripheral Nerve Interfaces (RPNIs) for high-fidelity control of neuroprostheses in amputees consist of a freely transferred muscle graft reinnervated by a residual nerve within the amputated limb. In previous RPNI surgeries, a small (~130 mg) graft of free skeletal muscle became quickly revascularized by collateral blood flow.[2,3] However, larger muscle grafts may increase electrical signaling capacity. Our purpose was to evaluate the effect on RPNI signaling capacity and tissue viability when a muscle graft with increasing muscle volume was implanted.

MATERIALS AND METHODS: Thirty F344 rats were assigned to one of five groups (n=6 per group). In RPNI groups, each RPNI was constructed of semimembranosus muscle allograft of approximately 150 mg (RPNI 150), 300 mg (RPNI 300), 600 mg (RPNI 600) or 1200 mg (RPNI 1200). Each RPNI graft was neurotized by the transected common peroneal nerve. In the negative control group, the peroneal nerve was transected and no muscle graft was implanted. After 3 months of recovery, RPNI compound muscle action potential (CMAP), force and histology were analyzed.

RESULTS: When dissected, all RPNIs appeared well vascularized with observable neurotization. The RPNI 150 and RPNI 300 groups significantly retained greater tissue volume than the RPNI 600 and RPNI 1200 ($p < .05$, Table 1). CMAP electrical signaling was significantly greater for RPNI 150 compared to RPNI 1200 ($p < .02$). Histology examination demonstrated small but healthy muscle fibers for RPNI 150 and RPNI 300, while the RPNI 600 and RPNI 1200 disclosed central areas lacking regenerating muscle fibers. No evidence of neuromas was found in RPNIs, while disorganized axonal sprouting was demonstrated in the negative control group.

CONCLUSION: RPNI electrical signaling capacity and tissue viability are optimal when smaller volumes (150 to 300 mg) of free skeetal muscle grafts than when larger volumes (600 to 1200 mg) are used for RPNI construction with neurotization by the peroneal nerve in a rat model.

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FIGURE LEGEND:

Table 1. Summary data of major outcomes (mean ± SEM), *indicates significance level of main effects for one-way ANOVA. Post-hoc multiple comparisons, **indicates different from RPNI-Control ($p < .05$).

	RPNI 150	RPNI 300	RPNI 600	RPNI 1200	*p*-value*
Number of rats evaluated	6/6	6/6	5/6	4/6	-
Mass implanted (mg)	171 ± 6	329 ± 7**	614 ± 9**	1213 ± 18**	<0.001
Muscle weight (mg)	72 ± 7	98 ± 4	134 ± 10**	183 ± 13**	<0.001
Muscle loss (%)	58.3 ± 3.7	70.2 ± 1.1**	78.1 ± 1.7**	85.0 ± 1.1**	<0.001
CSA (mm^2)	7.04 ± 0.77	9.54 ± 0.70	12.56 ± 0.98**	13.97 ± 1.21**	<0.001
CMAP (mV)	**6.6 ± 1.3**	**4.7 ± 0.8**	**3.1 ± 0.6**	**2.3 ± 0.7****	**<0.02**
Tetanic Force (mN)	289 ± 43.3	259 ± 49.8	235 ± 75.8	116 ± 31.0	>0.20