Myoelectric Signal Transmission from Implanted Epimysial Electrodes Using Bone-Anchor as Conduit

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INTRODUCTION

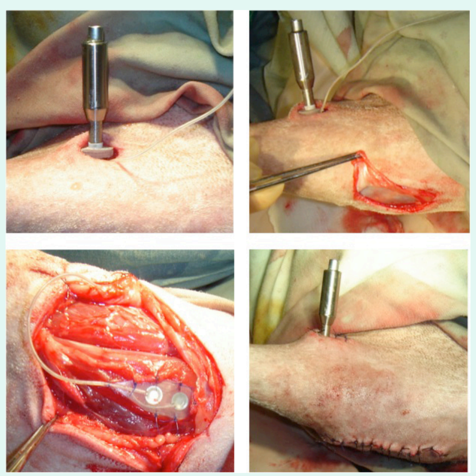
Prostheses remain the mainstay of rehabilitation in upper limb loss. This presents the wearer with 2 problems: attachment and control. Bone-anchored devices can be used to overcome problems with prosthetic attachment and additionally used to transfer control signals from implantable electrodes to the prosthesis, addressing shortfalls associated with surface electrodes. [1]

In above-elbow amputees, targeted muscle reinnervation (TMR) enables more signal generation by redirecting nerves previously controlling the amputated muscles in the forearm, to surrogate muscles in the torso (e.g. pectoralis major). [2]

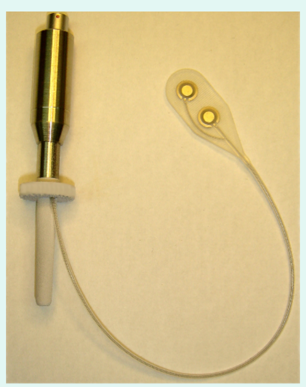
We describe in vivo model using implantable electrodes to record myoelectric signals (MES) in normal muscles and following TMR, utilizing a bone-anchor as a conduit to carry signals across the skin barrier.

MATERIALS AND METHODS

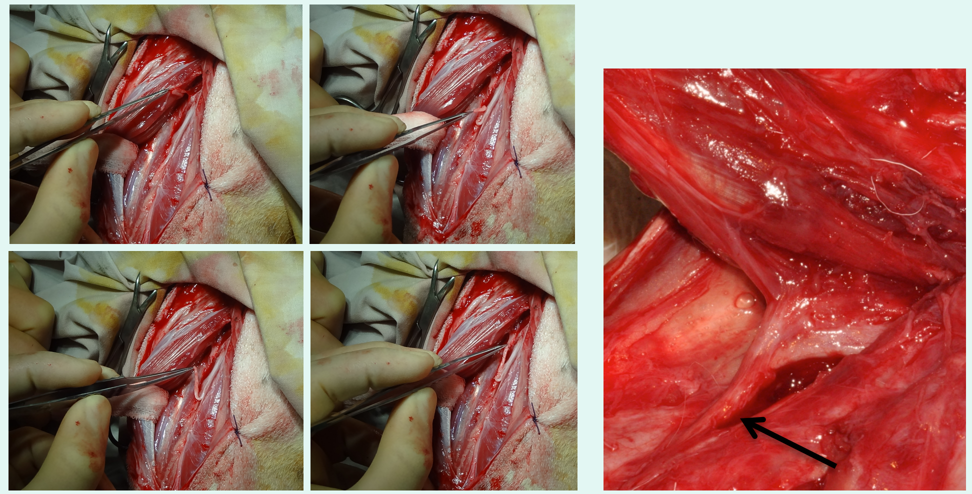
An in vivo n=6 ovine model was used. A bone-anchor was placed trans-tibially and bipolar electrodes sutured to proneus muscle.



Surgical steps in device insertion.



Bone-anchor/electrode device

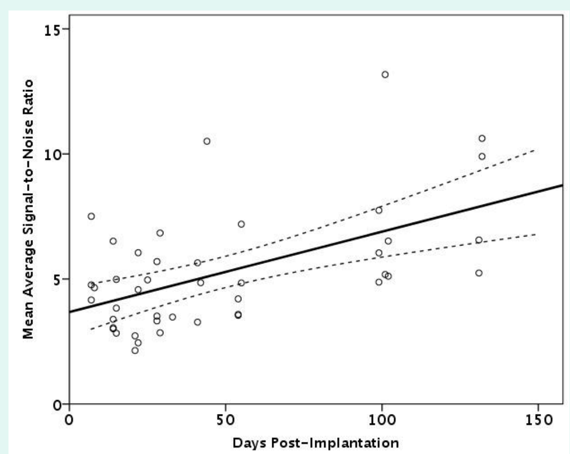


Left – surgical steps in TMR surgery. Right – coaptation site (arrow) at 12 weeks.

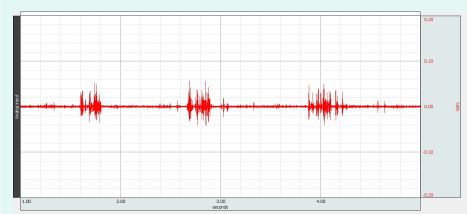
In a further n=1, motor nerve to PT was divided and coapted with a motor branch from peroneal nerve. Myoelectric signals (MES) were recorded over a 12-week period. Functional recovery in the TMR model was assessed by MES and force-plate analysis (FPA).

RESULTS

In n=6 group, there was a positive correlation between signal to noise ratio (SNR) and time since implantation ($p<0.005$), with a mean SNR of 7 by week 12.

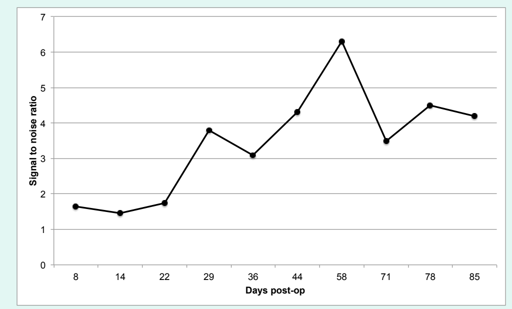


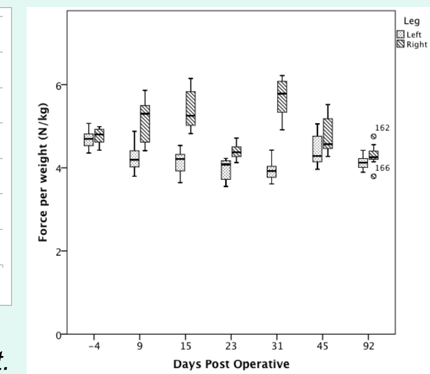
SNR scatter plot n=6 group.



Typical MES recordings.

In the TMR model, functional recovery was observed after 4 weeks. This turning point was closely related to a return to normal gait - pre-op: left 4.7N/kg, right 4.8N/kg; 45 days post-op: left 4.4N/kg, right 4.8N/kg, $p<0.05$. Recorded MES from TMR muscle compared favourably with healthy muscle.





Left – Mean SNR – TMR experiment.
Right - FPA box plot – TMR experiment.

CONCLUSIONS

We have demonstrated that a bone-anchor is a reliable and robust conduit for transmitting MES over a period of 12 weeks. The combination of implanted electrodes & direct skeletal fixation offers clear advantages over current systems for prosthetic attachment & control. This system forms the basis of a complete solution for prosthetic rehabilitation, which can also be used in the context of TMR.

REFERENCES

1. Al-Ajam Y, Lancashire H, Pendegrass C, et al. The use of a bone-anchored device as a hard-wired conduit for transmitting EMG signals from implanted muscle electrodes. IEEE Trans Biomed Eng. 2013;60(6):1654-9.
2. Kuiken TA, Dumanian GA, Lipschutz RD, Miller LA, Stubblefield KA. The use of targeted muscle reinnervation for improved myoelectric prosthesis control in a bilateral shoulder disarticulation amputee. Prosthet Orthot Int. 2004;28(3):245-53.

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