Ex vivo testing of a novel, tissue-preserving technology for battlefield deployment and limb perfusion support technology that provides long-term circulatory support to systemically-isolated injured limbs

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Objectives

Limb injuries are the most common combat injuries, representing ~70% of injuries in the Iraq/Afghanistan conflicts, with 5-7% resulting in major limb amputation. Under battlefield conditions, the priority is to preserve life, often leading to irreversible limb damage/amputation. To reduce limb loss rate, we have developed limb salvage technology suitable for austere environments. The point of contact technology has two components, aimed at preserving limbs at injury site and during clearance/transportation. A dual, pneumatic tourniquet isolates the limb and controls haemorrhage, and a cooling sock reduces metabolic requirements and enhances viability. The third component (perfusion technology) is not field-deployed (used in field hospitals). Using our mini-integrated ECMO, coupled with automated control and encasement technology, our limb life support technology supports prolonged tissue metabolism and circulation, permitting staged surgical intervention. This technology chain was tested using disarticulated ovine hind limbs, mimicking the most extreme scenario–salvaging a fully disarticulated limb beyond 3hrs.

Methods

Freshly disarticulated limbs were collected (point of contact) and assessment of prolonged muscle viability performed under three conditions: Non-cooled, non-perfused (NC-NP, no intervention); perfused-cooled (NC-P), and; cooled-perfused (C-P) (n=3 per group). Cooled limbs placed in the cooling sock throughout transit/evacuation, and perfused limb groups placed on limb life support technology (arrival at military medical facility). Femoral artery and vein were cannulated and limb heated and oxygenated for 2hrs. Tissue viability assessment was at 1hr (baseline) and 3hr post-disarticulation, performed using nerve stimulation on intact muscle.

Results

Mean±SD deep tissue cooling after 1hr was 8.56 ±1oC for cooled groups. Limbs were perfused 77±17min post-disarticulation. For nerve stimulation (observable twitch threshold (in mA for 1s)), all groups displayed baseline muscle activity 1hr post-disarticulation; C-P 21±20.5; NC-P 85±18; NC-NP 33±26.5. At test endpoint, C-P and NC-P values were 50±69.3 and 22±13.5, respectively, and no muscle activity shown in non-intervention group.

Discussions

We sustained considerable muscle nerve activity in both perfused groups at 3hr post-disarticulation, whilst non-intervention limbs showed no activity. Our technology focuses on ultimately maximising functional recovery. The field-deployable system is suitable for frontline trauma care in austere environments, and designed to support tissue salvage and regeneration.

Keywords: tissue preservation technology, battlefield deployment, limb injury, long-term circulatory support