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Prophylactic fasciotomy in a porcine model of extremity trauma

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ABSTRACT

Background: Extremity injury, with concomitant hemorrhagic shock, can result in ischemia–reperfusion injury and the formation of compartment syndrome requiring fasciotomy. As the benefit of prophylactic fasciotomy is unclear, the objective of this study is to determine the functional recovery of an ischemic limb with hemorrhagic shock after prophylactic fasciotomy.

Material and methods: Yorkshire swine underwent 35% blood volume hemorrhage, followed by 1, 3, and 6 h of ischemia ($n = 17$; 1HR, 3HR, and 6HR) via iliac artery occlusion followed by repair and reperfusion. A second cohort ($n = 18$) underwent fasciotomy of the anterior compartment of the hind limb following vascular repair (1HR-F, 3HR-F, and 6HR-F). Compartment pressures, measures of electromyographic (EMG) recovery, and a validated gait score (modified Tarlov) were performed throughout a 14-d survival period.

Results: Increasing ischemic intervals resulted in incremental increases in compartment pressure ($P < 0.05$), although the mean did not exceed 30 mm Hg. EMG studies did not show a significant improvement comparing the 3HR with 6HR groups. There was a significant improvement in the EMG studies within the 3HR-F, when compared with 6HR-F. There was a trend toward sensory improvement between the 3HR-F and 3HR groups. However, this did not translate to a difference in functional outcome as measured by the Tarlov gait score.

Conclusions: Within this swine model of hemorrhagic shock and hind limb ischemia, the use of prophylactic fasciotomies did not improve functional outcome.

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1. Introduction

Extremity vascular trauma represents 75%–88% of vascular injury in the wars in Iraq and Afghanistan [1–3], with limb salvage attempted in almost 80% of patients [4,5]. This is higher than in previous conflicts, largely due to a reduction in prehospital transport time and the availability of adjuncts, such as temporary vascular shunts, which can increase the physiological window for limb salvage [6].

Limb salvage is dependent on the early restoration of arterial inflow and venous outflow in addition to the mitigation of reperfusion injury [7]. A local effect of reperfusion injury is tissue edema driven by the inflammatory process initiated by ischemic insult. If the resultant increase in compartment pressure exceeds the capillary pressure, limb viability can become compromised, a pathology known as compartment syndrome [8,9]. Although compartment syndrome is a clinical diagnosis and there is no standard quantitative definition, an absolute pressure >30 mm Hg is considered a risk factor for compartment syndrome [10]. The clinical standard of practice for ameliorating extremity compartment syndrome is fasciotomy.

Although the benefit of fasciotomies in clinically established compartment syndrome is unquestioned, prophylactic use following emergent revascularization is less clear [10,11]. The use of fasciotomy in limb salvage has the potential to maximize functional outcome; however, fasciotomies are not without morbidity and can result in significant reconstructive soft tissue complications [12]. Specifically, what is unclear is the optimal ischemic time and compartment pressure threshold for fasciotomy to achieve maximal benefit in functional outcome.

The purpose of this study was to evaluate the effect of prophylactic fasciotomy on neuromuscular recovery, laboratory markers of ischemia–reperfusion, and tissue injury as determined by histologic evaluation. We hypothesized that prophylactic fasciotomy would facilitate the preservation of limb function and improve neuromuscular recovery when compared with a treatment modality that did not include fasciotomy.

2. Methods

Institutional Animal Care and Use protocol review and approval was obtained for the study. All studies were performed at the accredited laboratories of the United States Army Institute of Surgical Research at Fort Sam Houston, TX. This study used female Yorkshire swine of weights ranging from 70–90 kg (*Sus scrofa*; Midwest Research Swine, Gibbon, MN). On arrival, swine were housed for 7 d before their use in experimental protocols for quarantine and acclimation.

2.1. Study design

On the day of surgery, swine were randomized into one of six experimental groups as follows: vascular injury—1, 3, or 6 h of ischemia without fasciotomy (1HR, 3HR, and 6HR) or vascular injury—1, 3, or 6 h of ischemia with prophylactic fasciotomy (1HR-F, 3HR-F, and 6HR-F). The study was executed in five phases as described in the following and outlined in Figure 1.

2.2. Preparation

Induction of anesthesia was achieved with an intramuscular (IM) injection of ketamine (15–20 mg/kg IM), atropine (0.04–0.4 mg/kg IM), and surgical plane of anesthesia maintained with 2%–4% isoflurane following orotracheal intubation. All surgical procedures were performed using sterile precautions with the animal in the supine position. A fentanyl patch (25 mcg/hr) was placed before surgery to ensure effective postoperative pain control.

Using a midline cervical incision, the right common carotid and internal jugular vein were cannulated to permit intravenous fluid resuscitation and arterial pressure monitoring. A lower abdominal midline incision was performed to expose the right external iliac artery via dissection of the preperitoneal plane. A 5–6-cm segment of the vessel was exposed using the bifurcation of the femoral arteries serving as the distal landmark. The lateral circumflex artery was also identified and ligated to reduce the collateral arterial extremity inflow. Silastic vessel loops were used to gain hemostatic control, and the right external iliac artery cannulated with an 8 Fr catheter for the purpose of simultaneously achieving controlled hemorrhage and inducing vascular extremity injury and ischemia.

2.3. Hemorrhage, shock, and resuscitation

Hemorrhagic shock was induced using a previously described and accepted methodology [13]; briefly, 35% of swine total blood volume was withdrawn through the iliac catheter over 20 min with half of that volume withdrawn over the first 7 min and the remaining volume of the next 13 min. Control and accuracy of volume withdrawal was ensured by the use of a computer-driven rotary pump (Masterflex Easy Load II; Cole–Parmer, Vernon Hills, IL). The animals then remained in untreated hypovolemic shock for 30 min. At the completion of the shock period, maintenance intravenous fluid (normal saline at 150 cc/h) was started. Animals were resuscitated using autologous fresh whole blood collected during the controlled hemorrhage phase and normal saline boluses (500 cc) to achieve and maintain a mean arterial pressure of ≥60 mm Hg.

2.4. Ischemic interval

Subsequent to the shock interval and restoration of blood pressure, animals were randomized into the previously described six experimental groups. Limb ischemia was achieved by clamping the external iliac artery, abolishing distal flow, which was confirmed by Doppler.

2.5. Arterial reconstruction and fasciotomy

After the assigned ischemic interval, restoration of blood flow to the hind limb was achieved by performing a patch angioplasty. The resultant puncture wound from the cannula removal was extended proximally and distally for an incision