Injury, Int. J. Care Injured 47 (2016) 1903–1907

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Optimization of indirect pressure in order to temporize life-threatening haemorrhage: A simulation study

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ARTICLE INFO

Article history:
Accepted 3 June 2016

Keywords:
Junctional trauma
External aortic compression
Compression
Noncompressible haemorrhage

ABSTRACT

Background: Minimizing haemorrhage using direct pressure is intuitive and widely taught. In contrast, this study examines the use of indirect-pressure, specifically external aortic compression (EAC). Indirect pressure has great potential for temporizing bleeds not amenable to direct tamponade i.e. abdominal-pelvic, junctional, and multi-site trauma. However, it is currently unclear how to optimize this technique.
Methods: We designed a model of central vessel compression using the Malbrain intra-abdominal pressure monitor and digital weigh scale. Forty participants performed simulated external aortic compression on the ground, on a stretcher mattress, and with and without a backboard.
Results: The greater the rescuer's bodyweight the greater was their mean compression (Pearson's correlation 0.93). Using one-hand, a mean of 28% participant bodyweight (95% CI, 26–30%) could be transmitted at sustainable effort, waist-height, and on a stretcher. A second compressing hand increased the percentage of rescuer bodyweight transmission 10–22% regardless of other factors (i.e. presence/absence or a backboard; rescuer position) ($p < 0.001$). Adding a backboard increased transmission of rescuer bodyweight 7–15% ($p < 0.001$). Lowering the patient from waist-height backboard to the floor increased transmission of rescuer bodyweight 4–9% ($p < 0.001$). Kneeling on the model was the most efficient method and transmitted 11% more weight compared to two-handed maximal compression ($p < 0.001$).
Conclusions: Efficacy is maximized with larger-weight rescuers who use both hands, position themselves atop victims, and compress on hard surfaces/backboards. Knee compression is most effective and least fatiguing, thus assisting rescuers of lower weight and lesser strength, where no hard surfaces exist (i.e. no available backboard or trauma on soft ground), or when lengthy compression is required (i.e. remote locations). Our work quantifies methods to optimize indirect pressure as a temporizing measure following life-threatening haemorrhage not amenable to direct compression, and while expediting compression devices or definitive treatment.

Introduction

Following severe penetrating abdominal-pelvic trauma, the goal is to limit blood loss while expediting transfer to definitive care and operative rescue. Currently, few temporizing preoperative strategies are widely available beyond haemostatic dressings [1] hypotensive resuscitation [2], and balanced transfusion [3]. Unfortunately, abdominal-pelvic, or junctional haemorrhage- namely, that which occurs between the inguinal ligament and umbilicus, groin, buttocks, pelvis and perineum- is often not amenable to direct compression [4]. Therefore, rupture of the vessels underlying the torso- such as the internal and external iliac, common femoral arteries and abdominal aorta- remains a leading causes of preventable post-traumatic haemorrhagic death [5,6].

Combined data from the Joint Trauma Theater Registry (380 patients) and the National Trauma Data Bank (7020 patients) reports that non-compressible iliac artery injury was responsible for 7.4% of deaths in conflict zones and 9.9% of civilian deaths, whereas abdominal aortic injuries killed 0.8% of patients in conflict zones, and 6.1% in civilian settings [7]. Accordingly, novel life-saving abdominal-pelvic tourniquets [8–12] and haemostatic

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http://dx.doi.org/10.1016/j.injury.2016.06.009
0020-1383/

dressings [1,13,14] have been developed. Unfortunately, these innovations may not be immediately available in austere environments, may not be carried by all first responders, take time to learn, take time to apply, and may not temporize all junctional injuries. Alternatively, or while awaiting device application, some military medics learn to press a fist or knee over the abdomen or pelvis [15]. While not yet widely taught to civilian rescuers, external aortic compression (EAC)- namely, applying pressure on the external abdomen at a site that approximates the supra-umbilical aorta proximal to its bifurcation- has successfully temporized major haemorrhage following post-partum haemorrhage [16], and abdominal aortic aneurysm rupture [17]. However, it is unclear how to optimize this technique and how widely it could be applied.

Use of EAC (by one of these authors- MJD) has been reported following a single case of civilian penetrating trauma responded to by a single off-duty rescuer [18]. Direct pressure was impossible due to multiple distal gunshot wounds [19]. Instead, the single rescuer used bimanual supra-umbilical EAC to arrest external haemorrhage and restore consciousness to the victim. The patient ultimately died, but this was most likely because EAC could no longer be optimized. For example, external haemorrhage resumed when roadside EAC was performed by a lesser-weight rescuer, and again during ambulance transfer by larger-weight rescuers but atop a soft ambulance mattress and at the rescuer's waist height [18]. This study hopes to optimize the use of EAC and indirect pressure. While our primary goal is to provide another clinical tool to temporize major junctional abdominal-pelvic haemorrhage, these findings might apply to any major haemorrhage requiring compression.

Materials and methods

Study design

This was a prospective, cross-over simulation study of compression optimization. Manual pressure haemostasis scenarios were simulated on May 15th, 16th and 17th, 2013. Participants completed the scripted scenarios independently, and performed the crossover on the same day. Study participants were blinded to their own and others' compression weight and pressure, as well as the purpose of the study, in order to minimize preparation bias. The manoeuvres were performed in alternating order, once participants were separated by sex, to control for skill acquisition and fatigue and the effect of males' disproportionately greater upper body strength. This study received approval from our institutional Ethics Review Board and all participants provided written informed consent.

Setting

Our participants were recruited from the Royal Alexandra Hospital Emergency Department (ED) and the General Systems Intensive Care Unit (ICU) of the University of Alberta Hospital, both in Edmonton, Alberta, Canada. The ED is in a large community hospital trauma center that has an annual census of over 75,000 annual visits. The ICU unit has 30 beds, >90% occupancy and is a tertiary referral center with over 1500 annual admissions.

Selection of participants

Recruited participants were registered nurses and physicians at either hospital setting. A convenience sample was used, participation was completely voluntary and participants were provided coffee and donuts for their participation.

Methods of measurement and outcome measures

Our model consisted of a high-capacity digital medical weight scale (Seca 874, Hamburg) and atop it a modified Malbrain intra-abdominal pressure monitoring system [19]. An 18-French Foley catheter was inserted into the drip-chamber port of a 250 mL saline bag; the balloon inflated and drawn taught, and the hole sealed with dermabond™ cyanoacrylate (Ethicon, New Jersey). The system was zeroed to 0–2 mmHg via a conical luer-lock adapter, inserted into the Foley drainage-port; attached to a stopcock and plugged into a MRX Heartstart monitor™ (Philips, Amsterdam). The saline-bag was covered with a folded hospital blanket such that the pressure was 3–5 mmHg (normal intra-abdominal pressure).

This model (Fig. 1) was placed on a cement floor, and on a waist-high standard mattress atop a standard emergency room stretcher (Stryker, Michigan), and with and without a standard backboard (Ferno, Ohio) between the model and the mattress. We recorded both compression weight (kg) and compression pressure (mmHg) in order to build upon (and compliment) the existing literature [15,20].

Participants followed scripted instructions to compress with one then two hands, and were permitted to compress as they would in clinical practice, using either the heel of their hand or fist. Participants were asked to apply "sustainable effort" (explained as the amount of effort that they felt they could maintain for a 40-min transport), and "maximal effort" (explained as the most compression they could generate in a steady fashion for approximately two minutes at a roadside). Participants also compressed with their knee (at ground level only). Because our study participants were on-shift clinicians their pre-assigned work precluded a full 40 min of compression. However, separately, two male and two female

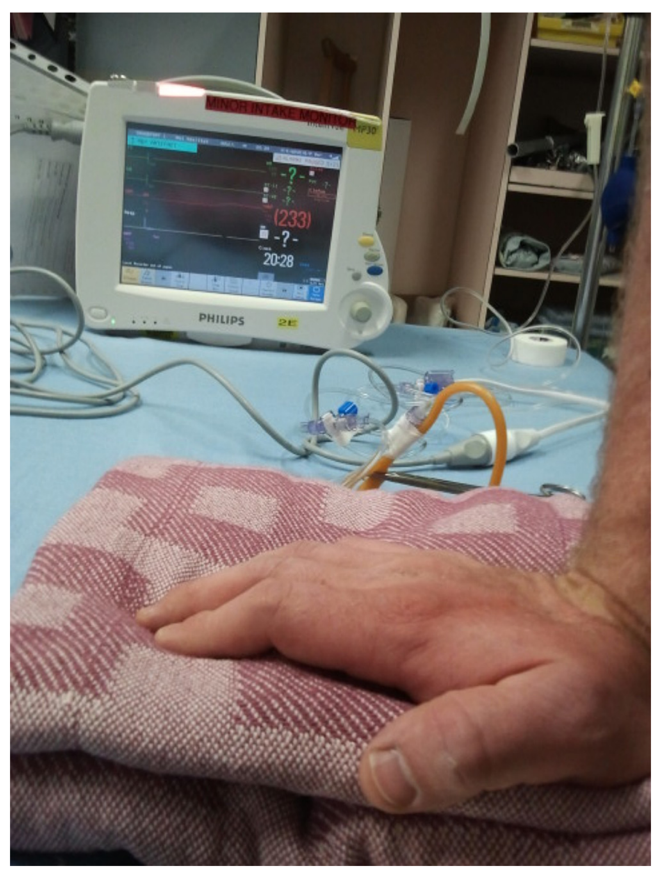

Fig. 1. Abdominal compression model.