Abdominal Aortic and Iliac Artery Compression Following Penetrating Trauma: A Study of Feasibility

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Abbreviations:
ED: emergency department
ICU: intensive care unit
MEAC: manual external aortic compression

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Abstract

Introduction: Penetrating junctional trauma is a leading cause of preventable death on the battlefield. Similarly challenging in civilian settings, exsanguination from the vessels of the abdomen, pelvis, and groin can occur in moments. Therefore, iliac artery or abdominal aortic compression has been recommended. Based on prior research, 120 lbs (54 kg) or 140 lbs (63 kg) of compression may be required to occlude these vessels, respectively. Whether most rescuers can generate this amount of compression is unknown.

Objective: To determine how many people in a convenience sample of 44 health care professionals can compress 120 lbs and 140 lbs.

Methods: This study simulated aortic and iliac artery compression. Consent was obtained from 44 clinicians (27 female; 17 male) from two large urban hospitals in Edmonton, Alberta, Canada. Participants compressed the abdominal model, which consisted of a medical scale and a 250 ml bag of saline, covered by a folded hospital blanket and placed on the ground. In random order, participants compressed a force they believed maintainable for 20 minutes ("maintainable effort") and then a maximum force they could maintain for two minutes ("maximum effort"). Compression was also performed with a knee. Descriptive statistics were used to evaluate the data.

Results: Compression was directly proportional to the clinician's body weight. Participants compressed a mean of 55% of their body weight with two hands at a maintainable effort, and 69% at a maximum effort. At maintainable manual effort, participants compressed a mean of 86 lbs (39 kg). Sixteen percent could compress over 120 lbs, but none over 140 lbs. At maximum effort, participants compressed a mean of 108 lbs (48 kg). Thirty-four percent could compress greater than 120 lbs and 11% could compress greater than 140 lbs. Using a single knee, participants compressed a mean weight of 80% of their body weight with no difference between maintainable and maximum effort.

Conclusion: This work suggests that bimanual compression following penetrating junctional trauma is feasible. However, it is difficult, and is not likely achievable or sustainable by a majority of rescuers. Manual compression (used to temporize until device application and operative rescue) requires a large body mass. To maintain 140 lbs of compression (for example during a lengthy transport), participants needed to weigh 255 lbs (115 kg). Alternatively, they needed to weigh 203 lbs (92 kg) to be successful during brief periods. Knee compression may be preferable, especially for lower-weight rescuers.

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Introduction

Life-threatening abdominal aortic, iliac, and femoral vascular injuries occur in both military and civilian settings.[1] Trauma to the thoraco-axillary and, more commonly, the abdominal-pelvic region is often referred to as junctional trauma, which has been reported in American,[2] Canadian,[3] British,[4] and Israeli military personnel.[5] Junctional trauma is a leading cause of potentially survivable battlefield death.[2] Deep vascular structures can be damaged by improvised explosive devices, gunshots, and vehicle collisions, and lethal exsanguination can occur within minutes. Therefore, there have been calls for more research, and for novel clinical interventions.[2,6,7]

Direct pressure and hemostatic dressings have saved many lives following extremity hemorrhage.[8] However, they typically cannot be used for injury above the inguinal

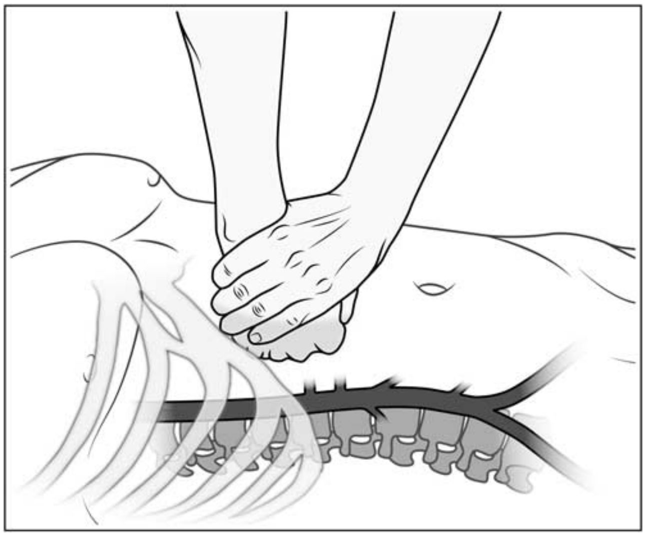

Figure 1. Manual External Aortic Compressions

ligament.[9] Therefore, proprietary devices have been developed for junctional trauma.[6] These include a novel abdominal aortic tourniquet that has been shown to reduce femoral artery flow substantially in humans.[10,11] Unfortunately, these devices are not widely available, and require time and training to apply. As such, using the rescuer's hands to temporize life-threatening hemorrhage seems intuitive.

Military medics have been instructed to press both hands above the umbilicus in order to extinguish flow below the abdominal aorta. Blavais et al also suggested compression with a single knee.[12] However, there is minimal evidence regarding whether this is feasible or sustainable for most rescuers. Blaivas did conduct a small (n = 9) study by placing weights on the abdomen of military volunteers, and determining when Doppler flow was extinguished. They concluded that 120 lbs of pressure was required to guarantee occlusion of internal iliac artery flow, and 140 lbs for distal abdominal aortic flow.[12] It is unclear whether civilian clinician rescuers (or most soldiers) can achieve this level of compression.

Manual external aortic compression (MEAC) (Figure 1) has been deployed successfully following postpartum hemorrhage[13] and ruptured abdominal aortic aneurysm.[14] It also has been applied successfully to restore consciousness to a roadside victim of multiple abdominal and pelvic gunshots.[15] However, when handed off to a smaller rescuer, this victim again started to bleed, and again became unconscious. Following successful resumption of aortic compression by the first compressor, a paramedic weighing over 200 lbs took over. This third rescuer did stop bleeding on the roadside, but could not maintain it during a ten minute ambulance transfer. Ultimately, the patient died. This report showed that while MEAC can be successful, it may not be widely achievable or maintainable. This study was undertaken to build upon Blaivas et al and to examine a possible relationship between rescuer body weight and successful abdominal compression.

Methods

This participant-blinded, simulation study of deep vessel compression enrolled clinician volunteers from a large urban trauma center emergency department (ED) and a large academic university hospital intensive care unit (ICU), in Edmonton, Alberta, Canada (population 1 million). The ED has an annual census of 75,000 and the ICU has 26 beds and > 90% occupancy. Written informed consent was obtained from all participants and approval obtained from the University of Alberta's Institutional Review Board.

The simulation model consisted of a folded hospital blanket over a 250 ml bag of saline. This was placed atop a high-capacity medical scale (Seca Scales Model 874, Hamburg, Germany) and on a cement floor. Participants compressed the simulation model with their fist covered by their second hand (Figure 1), and then with their knee. They were read a script of instructions to compress the model with a force they thought they could maintain for a 20 minute transport (ie, a maintainable effort). They also were instructed to apply a maximum effort that they could exert for two minutes (ie, a maximum effort). Maneuvers were performed in alternating order, controlling for fatigue and skill acquisition. Participant weight was then determined by having them stand on the same medical scale with the simulation model removed. All participants were blinded to all results, which were recorded in the researcher's notebook. Data was entered into a Microsoft Excel spreadsheet Version 7.0.25 (Microsoft Corporation, Redmond, Washington USA) and descriptive statistical analysis was performed. These results represent preliminary findings from a larger, ongoing investigation into what variables affect manual hemorrhage control.

Results

Forty-four Doctor of Medicine and Registered Nurse participants were enrolled, and all completed the study. Twenty-seven were females (61%) with a mean weight of 143 lbs (range, 95-189 lbs). Seventeen were males (39%) with a mean weight of 174 lbs (range, 120-240 lbs). Mean weight of all participants was 156 lbs (range, 95-240 lbs).

Compression was proportional to rescuer body weight in a linear fashion and with a Pearson's correlation of 0.9311. This relationship held, regardless of whether effort was maintained or maximum. At maintainable effort (Table 1), participants compressed a mean of 86 lbs (range, 37-132 lbs). Seven of 44 (16%) compressed over 120 lbs, but none compressed over 140 lbs. At maintainable effort, the mean weight compressed by women was 77 lbs (range, 37-102 lbs) and men 101 lbs (range, 59-132 lbs). Expressed as proportion of body weight, women maintained 53% and men 57% of their body weight.

At maximum effort (Table 2), participants compressed a mean of 109 lbs (range, 55-157 lbs). Fifteen of 44 (34%) compressed greater than 120 lbs. Five of 44 (11%) compressed greater than 140 lbs; all five of these participants weighed over 200 lbs. At maximum effort, the mean weight compressed by women was 100 lbs, and for men it was 122 lbs. As a proportion of body weight, women compressed a mean of 68% and men a mean of 72% at maximum effort. All reported subjective fatigue within two minutes.

Participants compressed the largest percentage of body weight when they used a single knee. With this method, they compressed a mean of 80% of body weight. There was no difference between knee compressive force when asked to compress with either maintainable effort or maximum effort. When using a single knee, no participants had subjective or objective fatigue within two minutes.

Effort	Maintainable		Maximum		Knee	
	Mean	Range	Mean	Range	Mean	Range
Women	77	37-102	98	55-124	113	71-146
Men	101	59-132	121	90-157	174	96-204
Both	86	37-132	108	55-157	120	71-204

Table 1. Weight in Pounds Compressed by Participants

Effort	Maintainable		Maximum		Knee	
	Mean	Range	Mean	Range	Mean	Range
Women	53%	44%-59%	68%	60%-75%	79%	79%-83%
Men	57%	48%-63%	71%	70%-78%	82%	81%-85%
Both	55%	44%-63%	69%	60%-78%	80%	79%-85%

Table 2. Percentage of Body Weight Compressed

Discussion

Lethal exsanguination can occur from the common femoral artery in less than two minutes.[16] As a result, temporizing measures need to be deployed immediately. A technique such as bimanual compression, which requires no equipment and minimal instruction, would minimize logistics, cost, and delays. However, this study suggests that while bimanual compression is feasible, it is difficult for the majority of rescuers to achieve, and even harder to maintain.

This research builds upon the work of Blauvais et al.[12] For clinician rescuers to achieve 140 lbs of compression, and maintain this for only two minutes, participants needed to weigh an average of 203 lbs. If the goal was to maintain compressive effort (eg, during transport, while awaiting device application, or while awaiting surgical rescue), then single rescuers needed to weigh an average of 255 lbs. Of note, even this may be an underestimate given that compression was performed against a hard surface. In contrast, patients often are injured on soft ground, and transported on a soft mattress (with or without a backboard).

The data suggests that compression with a single knee may be preferable to use of both hands. Using a knee, clinicians weighing only 150 lbs could compress 120 lbs, and clinicians weighing 175 lbs could compress 140 lbs. This was also the least-fatiguing method. Therefore, while external compression is intended only to temporize prior to expeditious surgical rescue (or device application), knee compression may be the optimal equipment-free technique. This may be especially true for smaller rescuers, single rescuers, and during protracted rescues.

In 2009, the Combat Casualty Care Research Program of the United States Army promoted the use of junctional, truncal, and abdominal tourniquets. They also estimated that from October 2001 through May 2010, almost 300 of their casualties could have benefitted from iliac artery or abdominal aortic compression.[6] Regardless of the technique used, the immediate goal is to tamponade the bleeding vessel against the posterior vertebrae, and at its most distal point.[3] The ultimate goal is to temporize major hemorrhage, expedite operative rescue, and prevent avoidable death. Manual external aortic and/or iliac artery compression is not part of any published guidelines for penetrating or nonpenetrating trauma.[17,18] Clearly, more research and innovation is required.

Limitations

This study has several limitations. Participants may have overestimated their maintainable effort and their maximal effort is likely minimized without clinical urgency. In addition, this model has not been validated for trauma. The research presented is translational in nature and may not apply to actual clinical settings.

Conclusion

Manual compression of deep abdominal vessels, such as the iliac arteries and abdominal aorta, is feasible. However, it requires considerable effort and rescuers of large body weight (>200 lbs). Manual external aortic and/or iliac artery compression is not part of any published guidelines for penetrating or nonpenetrating trauma. However, it can be easily taught, immediately applied, and requires no extra equipment. This study shows that this technique has limitations and may not be achievable by a majority of rescuers. In contrast, using a knee may be superior, especially for lower-weight rescuers, and during protracted rescues.

References

1. Markov NP, DuBose JJ, Scott D, et al. Anatomic distribution and mortality of arterial injury in the wars in Afghanistan and Iraq with comparison to a civilian benchmark. *J Vasc Surg*. 2012;56(3):728-736.
2. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001-2011). *J Trauma Acute Care Surg*. 2012;73:S431-S437.
3. Pannell D, Brisebois R, Talbot M, et al. Causes of death in Canadian Forces members deployed to Afghanistan and implications on Tactical Combat Casualty Care Provision. *J Trauma Inj Infect Crit Care*. 2011;71(5 Supp 1):S401-S407.
4. Parker P. Consensus statement on decision making in junctional trauma care. *J R Army Med Corps*. 2011;157(3 Suppl 1):S293-S296.

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5. Katzenell U, Ash N, Tapia A, et al. Analysis of the causes of death of casualties in field military setting. *Mil Med*. 2012;177(9):1065-1068.
6. Kragh JF, Murphy C, Dubick MA, et al. New tourniquet device for battlefield hemorrhage control. *US Army Med Dep J*. 2011;(April-June):38-55.
7. Kelly JF, Ritenour AE, McLaughlin DF, et al. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003-2004 versus 2006. *J Trauma Inj Infect Crit Care*. 2008;64(Supplement):S21-S27.
8. Kragh JF, Littrel ML, Jones JA, et al. Battle casualty survival with emergency tourniquet use to stop limb bleeding. *J Emerg Med*. 2011;41(6):590-597.
9. Walker NM, Eardley W, Bonner T, Clasper J. UK combat-related pelvic junctional vascular injuries 2008-2011: implications for future intervention. *Bone Jt J Orthop Proc Suppl*. 2013;95-B(SUPP 8):13.
10. Lyon M, Shiver SA, Greenfield EM, et al. Use of a novel abdominal aortic tourniquet to reduce or eliminate flow in the common femoral artery in human subjects. *J Trauma Acute Care Surg*. 2012;73:S103-S105.
11. Taylor D, Coleman M, Parker P. The evaluation of an abdominal aortic tourniquet for the control of pelvic and lower limb hemorrhage. *Bone Jt J*. 2013; 95-B(Supp 26):8.
12. Blaivas M, Shiver S, Lyon M, et al. Control of hemorrhage in critical femoral or inguinal penetrating wounds–an ultrasound evaluation. *Prehosp Disaster Med*. 2006;21(6):379-382.
13. Soltan MH, Sadek RR. Experience managing postpartum hemorrhage at Minia University Maternity Hospital, Egypt: no mortality using external aortic compression. *J Obstet Gynaecol Res*. 2011;37(11):1557-1563.
14. Kin N, Hayashida M, Chang K, et al. External manual compression of the abdominal aorta to control hemorrhage from a ruptured aneurysm. *J Anesth*. 2002;16(2):164-166.
15. Acheson EM, Kheirabadi BS, Deguzman R, et al. Comparison of hemorrhage control agents applied to lethal extremity arterial hemorrhages in swine. *J Trauma Inj Infect Crit Care*. 2005;59(4):865-875.
16. American College of Surgeons Committee on Trauma. *Advanced Trauma Life Support for Doctors*. 9th ed. Chicago, Illinois USA; 2012.
17. Campbell J. *ITLS for Emergency Providers*, 7th ed. Upper Saddle River, New Jersey USA: Prentice Hall; 2011.
18. National Association of Emergent Medical Technicians and American College of Surgeons Committee on Trauma. *Prehospital Trauma Life Support*, 7th ed. Burlington, Massachusetts USA: Jones & Bartlett Learning; 2011.