Prospective evaluation of the correlation between torso height and aortic anatomy in respect of a fluoroscopy free aortic balloon occlusion system

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Background. *To report the lengths of key torso vascular and to develop regression models that will predict these lengths, based on an external measure of torso height (EMTH, sternum to pubis) in the development of a fluoroscopy-free balloon occlusion system for hemorrhage control.*
Methods. *We conducted a prospective, observational study at a Combat Support Hospital in Southern Afghanistan using adult male patients undergoing computed tomography (CT). EMTH was recorded using a tape measure and intra-arterial distance was derived from CT imaging. Regression models to predict distance from the common femoral artery (CFA) into the middle of aortic zone I (left subclavian artery to celiac trunk) and zone III (infrarenal aorta) were developed from a random 20% of the cohort and validated by the remaining 80%.*
Results. *Overall, 177 male patients were included with a median (interquartile range [IQR]) age of 23 (8) years. The median (IQR) lengths of aortic zone I and III were 222 (24), 31 (9), and 92 (15) mm. The mid-zone distance from the left and right CFA to zone I were 423 (27) and 418 (29) and for zone III 232 (21) and 228 (22). Linear regression models demonstrated an accuracy between 99.3% to 100% at predicting the insertion distance required to place a catheter within the middle of each aortic zone.*
Conclusion. *This study demonstrates the use of morphometric analysis in the development of a fluoroscopy-free balloon occlusion system for torso hemorrhage control. Further study in a larger population of mixed gender is required to further validate insertion models. (Surgery 2014;155:1044-51.)*

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HEMORRHAGE is the leading cause of potentially preventable death in military trauma.[1-3] The majority of hemorrhagic foci originate in noncompressible regions, such as the torso and junctional zones (groin and axilla), accounting for 86.5% of hemorrhage-related combat deaths.[4] Furthermore, almost 9 out of 10 deaths occur in the prehospital setting.[4] Current management relies on operative hemorrhage control, which is contingent on patients surviving to hospital admission.[5] Even then, many patients arrive in extremis, with circulatory collapse, where reactive maneuvers such as resuscitative thoracotomy and aortic cross-clamping yield few survivors.[6]

Resuscitative endovascular balloon occlusion of the aorta (REBOA) provides inflow control and afterload support to patients with circulatory collapse from hemorrhage.[7] It can either be inserted prophylactically in patients at risk of hemorrhage and then inflated in the event of a

Accepted for publication December 31, 2013.

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0039-6060/$ - see front matter

Published by Mosby, Inc.

http://dx.doi.org/10.1016/j.surg.2013.12.036

deterioration, or as a substitute to open cross-clamping in the moribund patient.[8] REBOA is designed as a proactive maneuver, which can be inserted in austere circumstances, providing a physiologic bridge to definitive hemorrhage control.

The clinical use of this technique was first described in the 1950s,[9] with further reports in the 1980s.[10,11] Despite some favorable outcomes, technological limitations relating to arterial access, balloon construction, and placement mean that its adoption was not widespread. However, following the evolution of endovascular surgery and the experience with aortic balloon occlusion during endovascular aneurysm repair,[12,13] many of these constrains have been overcome. The use of REBOA in traumatic hemorrhagic shock is currently being revisited clinically using "off-the-shelf" devices,[14] but there is also active research into trauma-specific catheters.[15]

To facilitate REBOA deployment, the aorta has been characterized into 3 functional zones: Zone I extends from the origin of the left subclavian to the celiac trunk, zone II is from the celiac trunk to the lowest renal artery, and the infrarenal aorta constitutes zone III (Fig 1).[7] Zones I and III serve as "landing zones" for occlusion in specific injury patterns. Zone I occlusion provides resuscitation in circulatory arrest and control for abdominal exsanguination and zone III occlusion is for ileofemoral junctional hemorrhage.[5]

Current technology requires fluoroscopy for precision placement, which limits the deployment of REBOA systems in the prehospital or emergency department setting. Unassisted blind insertion is fraught with potential complications, varying from aortic arch placement precipitating cerebral ischemia to iliac artery occlusion inadequately controlling inflow.

A potential solution to aid fluoroscopy-free placement is to use an external anatomic measure to predict internal vascular length. A linear relationship has been previously demonstrated between aortic length and torso height.[16] The aim of this study was to develop predictive models of REBOA insertion distance, based upon an external measure of torso height (EMTH) correlated with internal vascular distance, the accuracy of which will be then assessed using prospective EMTH data, collected in a realistic clinical setting.

METHODS

This prospective, observational study was performed after approval from the UK Royal Centre for Defence Medicine Academic Unit and

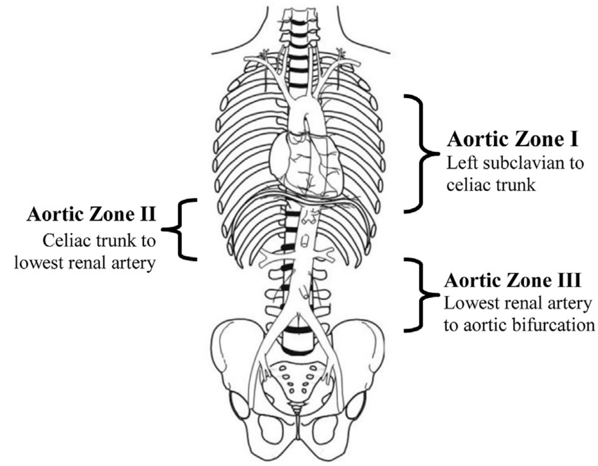

Fig 1. The three aortic zones. (Reproduced from Stannard A, Eliason JL, Rasmussen TE. Resuscitative endovascular balloon occlusion of the aorta (REBOA) as an adjunct for hemorrhagic shock. J Trauma 2011; 71:1869–72, with kind permission from Wolters Kluwer Health).

the US Medical Research and Material Command. The study was conducted at the Combat Support Hospital in Camp Bastion, Helmand Province, Southern Afghanistan. This hospital is unique in the theater of Afghanistan as it is a joint UK–US facility, staffed by clinicians from each nations military among others. It is also the busiest coalition medical facility in the region, providing comprehensive trauma care for both military and civilian patients.[17] The infrastructure includes two 64-slice computed tomography (CT) scanners, in addition to an emergency department, operating suite and critical care facilities.[18] Data was collected over 2 time periods (July 2011–September 2011 and November 2011–January 2012), during the deployments of 2 authors (AS and JJM).

Study population. A convenience sample of male patients aged between 18 and 50 years, who underwent contrast-enhanced CT imaging of the chest, abdomen, and pelvis as part of their care, were included in the study. A convenience sample was used, rather than consecutive patients, because of the brisk operational tempo and single-handed nature of the data collection. Nation status was dichotomized into patients of Afghan origin (military or civilian) and were termed "Host National" and the remaining were termed "Coalition Military." Enemy combatants were not included in the study.

Once a patient had been identified as requiring CT imaging, an EMTH was recorded before discharge. This was performed using a tape measure, held parallel to the subjects craniocaudal axis, to obtain the distance from the jugular notch