

Martial arts technique for control of severe external bleeding

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ABSTRACT

Objectives Haemorrhage control is a critical component of preventing traumatic death. Other than the battlefield, haemostatic devices, such as tourniquets or bandages, may not be available, allowing for significant avoidable blood loss. We hypothesised that compression of vascular pressure points using a position adapted from the martial art of Brazilian Jiu-Jitsu could be adapted to decrease blood flow velocity in major extremity arteries.

Methods Knee mount compression was applied to the shoulder, groin and abdomen of healthy adult volunteer research subjects from Seattle, Washington, USA, from March through May 2018. Mean arterial blood flow velocity (MAV) was measured using ultrasound in the brachial and femoral arteries before and after compression. A MAV decrease greater than 20% with compression was deemed clinically relevant.

Results For 11 subjects, median (IQR) MAV combining all anatomical locations tested was 29.2 (34.1, 24.1) cm/s at baseline and decreased to 3.3 (0, 19.1) cm/s during compression (Wilcoxon $p < 0.001$). MAV was significantly decreased during compression for each individual anatomical position tested (Wilcoxon $p \leq 0.004$). Per cent (95% CI) MAV reduction was significantly greater than 20% for shoulder compression at 97.5% (94% to 100%) and groin compression at 78% (56% to 100%), but was not statistically greater for abdominal compression at 35% (12% to 57%). Complete vessel occlusion was most common with compression at the shoulder (73%), followed by groin (55%) and abdomen (9%) (χ^2 LR, $p = 0.018$).

Conclusion The Brazilian Jiu-Jitsu knee mount position can significantly decrease blood flow in major arteries of the extremities. This technique may be useful for bleeding control after injury.

INTRODUCTION

Blood loss is the leading cause of preventable death after traumatic injury and is recognised as an important public health hazard.^{1,2} Bleeding control is even more important during mass casualty incidents which are becoming more commonplace worldwide. The American College of Surgeons Hartford Consensus on strategies to enhance survival in active shooter and intentional mass casualty events identified external haemorrhage control as a critical step in eliminating preventable prehospital death.³ In response, campaigns focusing on training the general public to intervene to stop bleeding have been established.⁴

In the USA, the 'Stop the Bleed' national campaign, endorsed by the American College of

Key messages

What is already known on this subject

- ▶ Blood loss is the leading preventable cause of death from trauma.
- ▶ There are no standardised and effective bystander interventions designed to reduce blood loss that do not require specialised equipment.

What this study adds

- ▶ In this study of healthy volunteers, we demonstrated that the Brazilian Jiu Jitsu knee mount position can be used to reduce blood flow in major limb arteries and may provide an effective bystander bleeding control intervention.

Surgeons, provides training to lay persons regarding the use of haemostatic devices and bandages.⁵ The training manual advocates the 'ABCs of Bleeding' that include (A)lerting medical responders, finding the (B)leeding injury and directly (C)ompressing the bleeding wound using the hands, followed by immediate bandage or tourniquet application.⁵ Similar national layperson training programmes have proliferated worldwide, including the Citizen AID campaign in the UK and the Singapore Secure campaign in Asia. Bleeding control kits are also being placed in public areas for use by the general public.

Tourniquets are most useful when used before onset of haemorrhagic shock.⁶ Experimental data examining blood loss using animal models suggest that over 60% of total blood volume can be lost and blood pressure reduced by over half after only 1 min of free bleeding from a femoral artery wound.⁷ Coincidentally, this is the same average amount of time required for medical personnel to deploy tourniquets during simulated bleeding situations, so significant blood loss can take place before and while tourniquets are being applied.⁸ In addition, not all bleeding can be effectively treated with a well-placed tourniquet. Wounds to large blood vessels in the anatomical junctions where limbs meet the torso (armpit and groin) must be treated with direct compression and wound packing. Several compressive devices have been designed for junctional wounds, but are not widely available, must be applied by trained healthcare providers and are generally lacking strong evidence for their use.⁹

A possible solution to this problem is use of a bleeding control technique that emphasises



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Figure 1 The Brazilian Jiu-Jitsu knee mount position. The practitioner applies downward compressive force using the knee and shin to pin a resisting opponent. (Demonstrated by EDS.)

compressing blood vessels at vascular pressure points by lay-rescuers. Guidelines have de-emphasised vascular pressure point compression in favour of tourniquets because of evidence demonstrating return of distal pulses during vascular compression using the fingers, which was attributed to user fatiguability and collateral circulation.^{10 11} An alternative compressive technique capable of applying more force over a wider area is found in the grappling-based martial art Brazilian Jiu-Jitsu. This position is known as the knee mount and is derived from the uki gatame or 'floating hold' of traditional Japanese jiu-jitsu and judo (figure 1). The technique is used to safely pin an opponent by applying downward pressure using the knee and shin using full bodyweight. The technique involves placing one knee or shin across the abdomen of a supine opponent while extending the other leg to provide both stability and balance. Full bodyweight force can be applied with the pinning leg and the position is comfortable for the user for long time periods. This position also allows the practitioner to maintain freedom of movement while keeping the head upright to maintain situational awareness and the hands available for other tasks.

We hypothesised that the knee mount position could be translated from a jiu-jitsu technique to a medical intervention capable of reducing blood flow in major limb arteries when applied to vascular pressure points. To test this hypothesis, we used a pre-post study design using ultrasound to measure blood flow velocity in the brachial and femoral arteries in healthy adult volunteers before and after applying compressive force using the knee mount position adapted for use at the shoulder, groin and abdomen.

METHODS

This was a prospective human volunteer study conducted in an academic research laboratory using a pre-post design to assess the effect of knee mount compression at the shoulder, groin and abdomen on blood flow velocity in the limbs.

Human subjects

The study protocol was developed in compliance with the Declaration of Helsinki for human research ethics and was approved by the Division of Human Subjects, University of Washington

(protocol #2669) prior to subject enrolment. Healthy non-pregnant, English speaking adults aged 18–55 without history of peripheral vascular disease, thromboembolism, anticoagulant use or major abdominal or extremity surgery were eligible for study enrolment and were recruited from the local population of Seattle, Washington, USA, over a 3-month period from March to May 2018. All subjects were provided an information sheet outlining risks and benefits and provided their consent prior to study enrolment. All study procedures were performed at the Emergency Medicine Research Laboratory, Seattle, Washington, USA. All data were held in a deidentified database for analysis.

Knee mount position

The knee mount position was taught directly to the senior author by Professor Eric Da Silva (Eric Da Silva Steel Blanket Brazilian Jiu-Jitsu, Woodinville, Washington, USA), who has over 20 years of experience training and teaching, having received his black belt (3rd degree) from Master Fabio Santos of San Diego, California, USA. Principles emphasised included appropriate maintenance of balance, control and application of weight emphasising use of the shin to maximise downward compressive force to desired anatomical locations (figure 2). The senior author then taught the positions to two previously untrained research associates, one male and one female, weighing 80 kg and 59 kg, respectively, who performed all of the techniques used on volunteers in this study.

Study procedure

Knee mount compression was tested in the same sequence starting at the shoulder, followed by the groin and abdomen for all subjects. (figure 2.) Subjects were placed in the supine position on a padded exercise mat. For brachial artery measurements, a linear array soft tissue ultrasound probe (GE Logiq-E9, GE Healthcare, Milwaukee, Wisconsin, USA) was used to first identify the brachial artery at the midpoint of the humerus using colour flow with the limb placed in an abducted and externally rotated position. A baseline measurement of blood flow velocity was then performed using pulse wave Doppler with the vessel visualised in longitudinal section. Peak systolic and end diastolic velocities were recorded according to automatic Doppler waveform analysis in cm/sec. For compression, a trained study team member then assumed the knee mount position with the shin applying compressive force at the shoulder. Ultrasound velocity measurements were then repeated during compression. The same procedures were then repeated at the leg by visualising the femoral artery at the medial thigh before and after assuming the knee mount position with the shin located at the inguinal groove overlying the inguinal ligament. Finally, blood flow velocity was again measured at the femoral artery at the thigh before and during application of the knee mount position with the shin placed on the upper abdomen perpendicular to the longitudinal body axis midway between the umbilicus and the inferior anterior rib margin. Up to three trials of compression were allowed for each anatomical location. Each compression trial was limited to 30 s duration and measurements were recorded when the research associate applying the technique reported maximal application of pressure. For each location, the average of up to three trials were calculated and one average peak systolic and end diastolic velocity measurement from each subject was used as a point estimate for each condition. Return to normal blood flow was confirmed in each vessel following release of compression.

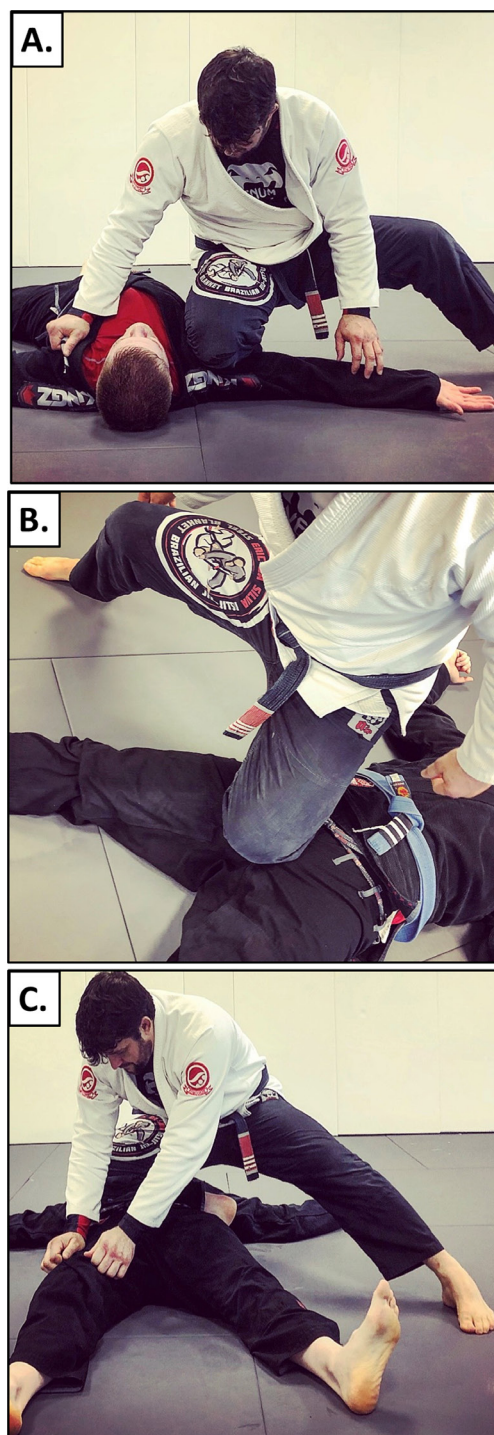


Figure 2 The Brazilian Jiu-Jitsu knee mount position modified to stop bleeding. The base position was modified to decrease blood flow in the brachial artery by compression at the shoulder (A), the femoral artery by compression at the groin (B) and the aorta by compression at the abdomen (C). (Demonstrated by EDS.)

Data analysis

Systolic and end diastolic blood flow velocities for each individual and condition were first converted to mean arterial velocity (MAV) using calculations used for mean arterial pressure using the formula:

End Diastolic Velocity + $\frac{1}{3}$ (Peak Systolic Velocity - End Diastolic Velocity)

The individual MAVs were then grouped according to condition and their distributions tested for normality using the Shapiro Wilk test for goodness of fit. Most distributions were found to be significantly skewed, so median (IQR) was used to describe upper and lower limits of each group. Wilcoxon Signed Rank test comparing groups for each anatomical location was then used to test for significant differences with $p < 0.05$ representing significance. Per cent change of MAV from baseline during compression was also calculated for paired measurements for all subjects and determined to be significant if the 95% CI of the change was less than and did not include a -20% change. In addition, the frequency of total vessel occlusion, defined as a 100% reduction of blood flow during compression, was calculated for each anatomical location tested.

Sample size estimate

The study was powered a priori to demonstrate what we felt to be a clinically relevant 50% reduction of blood flow velocity during compression, with a null difference of 20%, which would require at least 17 subjects to achieve 80% power to detect the difference with $\alpha = 0.05$. However, interim power analysis for effect size determination performed after enrolment of 10 subjects found a much larger overall reduction of blood flow velocity of 70%, conferring 98% power to show differences with $\alpha = 0.05$. The larger effect size was adequate to meet sample size requirements, so enrolment was stopped at 11 subjects.

RESULTS

Modification of knee mount technique for vascular compression

Several modifications to traditional knee mount were required to maximise vascular compression (figure 2). For the shoulder position, the rescuer's hand could also be placed on the victim's opposite shoulder for additional balance if needed and lifting the toes from the ground was not needed to achieve adequate vascular compression. For groin compression, the rescuer was turned to face the victim's feet and additional downward compressive force was applied by lifting the toes of the compressing leg from the floor and using a slight forward hip thrust. The hands could be used to further stabilise the position by holding the victim's hip or knee. For abdominal compression, the rescuer was also turned to face the victim's feet. The position of the rescuer's knee was also repositioned superior to the umbilicus to compress the aorta prior to its bifurcation. Lifting the toes of the compressing leg was required to increase compressive force along with a more significant forward hip thrust compared with the shoulder and groin positions. Balance could be improved by grasping the victim's hip or knee.

Effect on large artery blood flow

A total of 11 healthy adult subjects were screened and all were enrolled in this study. Mean (SD) age was 22.5 (6.3) years and 82% were male. There were no complications or injuries reported. Adequate velocity waveforms were obtained for all subjects at baseline and during compression (figure 3). Median (IQR) MAV for all subjects combining all anatomical locations tested was 29.2 (34.1, 24.1) cm/s at baseline without compression and decreased to 3.3 (0, 19.1) cm/s during compression (Wilcoxon $p < 0.001$), and velocity was significantly decreased during compression for each position tested (figure 4). The mean (95% CI) per cent change of baseline blood flow was -70% (-57% to -83%) overall for all anatomical locations tested. Per cent change of baseline blood flow at the brachial artery with

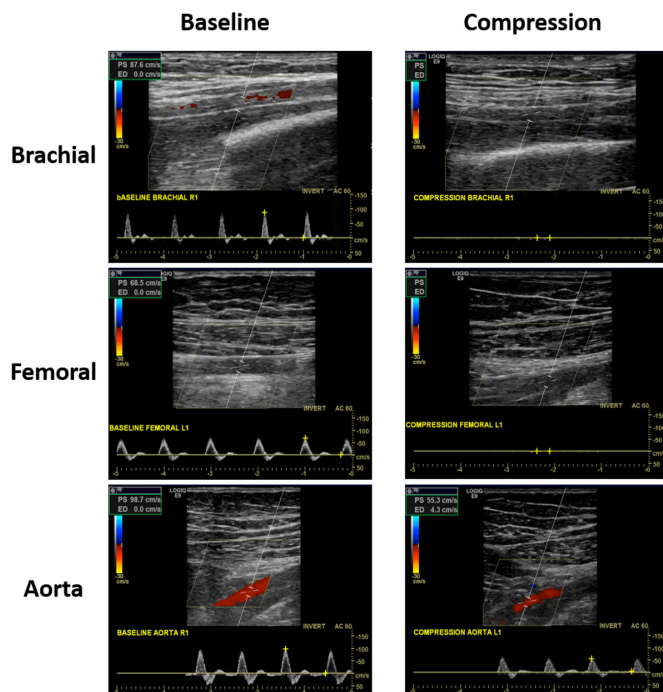


Figure 3 Screenshots of blood flow velocity at baseline and during knee mount compression. Blood flow velocity was measured at the brachial artery for shoulder compression and the femoral artery for both groin and abdominal aorta compression.

shoulder compression was -97.5% (-100% to -94%). Per cent change of blood flow from baseline at the femoral artery with groin compression was -78% (-100% to -56%). These positions both provided reductions of blood flow that were statistically greater than -20% . The per cent change from baseline femoral artery flow with aortic compression was -35% (-57% to -12%), which was not statistically different. Complete vessel occlusion was most common with brachial compression (73%),

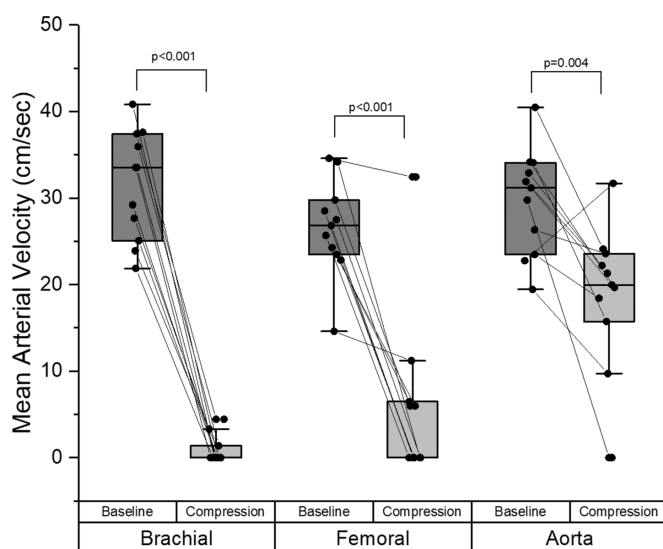


Figure 4 Box and whisker plots for the effect of knee mount compression on limb artery blood flow. Mean arterial velocity was decreased in all vessels measured during compression using the knee mount position. Boxes demonstrate median and IQR. Whiskers represent total range, including outliers. P values represent paired measurements tested using Wilcoxon Rank Sums for non-parametric data.

followed by femoral artery compression (55%) and aortic compression (9%) (χ^2 LR, $p=0.018$).

DISCUSSION

The results of this study support our hypothesis that the knee mount position can be used to decrease blood flow in major limb arteries when applied to vascular pressure points. Time to haemostasis is an important component of survival from trauma. The average time required for application of tourniquets or junctional compressive devices ranged from 60 to 87 s for three junctional tourniquets and was 66 s for extremity tourniquets when testing in simulated femoral artery bleeding models.^{8 12} The average diameter of the common femoral artery in 10 healthy 25.4 ± 3.3 -year-old males weighing 83 ± 11 kg was reported to be 9.0 ± 0.8 mm, yielding a potential bleeding surface area of 63.6 mm^2 for a complete common femoral arterial transection.¹³ Using our baseline velocity measurements for the femoral artery, the rate of bleeding in such a wound would approximate 17 mL of blood loss per second. Therefore, ignoring decreased bleeding rate as a result of falling blood pressure, a theoretical estimate for the maximum potential blood volume lost during 60–87 s of uncontrolled bleeding from this wound would range from 1020 to 1479 mL during the time required for tourniquet application. Application of bodyweight compression using the knee mount at the inguinal crease or mid abdominal aorta could theoretically decrease blood loss during the same time period by approximately 800–1153 mL (78% decrease) or 357–517 mL (35% decrease), respectively.

Current haemorrhage control methods emphasising vascular compression using the hands may reduce personal safety by taking attention away from possible environmental threats. There is evidence that this position is also very fatigable and may also discourage bystanders from intervening due to concerns over direct contact with bleeding wounds.¹⁰ The knee mount may be more efficacious because of less fatigue and may be safer as it enables a hands-free and heads-up position that can enhance situational awareness and ongoing threat assessment in a critical incident. This may be especially important in military or active shooter environments where ongoing threats to personal safety may be present. The knee mount position could also improve bystander willingness to intervene because it does not require direct contact with bleeding wounds.

According to Schroll *et al* who evaluated prehospital civilian tourniquet use in the USA, an average of 14 min elapsed from time of injury to tourniquet application by trained paramedics.¹⁴ Recognising the need for more rapid bleeding control interventions, a systematic review of the prehospital medical response to mass shooting of 1649 people concluded that equipment to control haemorrhage should be made widely available and advocated for public education on effective bleeding control.¹⁵ The knee mount position could fill the need for improved bleeding control prior to deployment of tourniquets or arrival of trained medical personnel. Refinement and dissemination of the knee mount position for bleeding control could fill a needed gap in the current approach to community bleeding control education efforts, namely a device-free method to reduce blood loss immediately that encourages bystander participation. Key steps needed to realise full translation to clinical use would include refinement of the technique, a standardised training programme, combining its use with deployment of tourniquets and further testing in simulated bleeding situations.

This study has several important limitations. First, we were unable to directly test effects of the knee mount compression

on volume of blood loss in injured humans. Our subjects were also healthy adults without known cardiovascular or peripheral vascular disease, which may require focused investigation in subjects having cardiovascular disease risk factors and differing body habitus. We did not test the effect of the knee mount on deployment of haemostatic devices. We also were not able to test more proximal blood flow in the iliac and axillary arteries that would provide direct support for utility with junctional wounds or for the effect of these positions on abdominal or pelvic bleeding. Finally, we acknowledge that this study was not a clinical trial, provided proof-of-concept only, and should not be generalised to clinical use without further study.

CONCLUSION

This study provides experimental evidence that the Brazilian Jiu Jitsu knee mount technique can reduce blood flow in major limb arteries when applied to healthy human volunteers for the purpose of vascular compression. This technique may be useful as a bystander bleeding control intervention when haemostatic devices or trained healthcare personnel are unavailable.

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Contributors NJW conceived the study, performed the experiments, performed the data analysis and drafted the manuscript. EDS inspired the study and provided critical technique training, suggestions and refinement. JPS assisted with subject recruitment and performed experiments. CH recruited study subjects, performed experiments and assisted with data analysis. All authors provided critical revisions to the manuscript and approved its final form.

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Competing interests EDS is owner of Eric Da Silva Brazilian Jiu-Jitsu, Woodinville, Washington, USA.

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Data sharing statement Study data are available on request to the senior author.

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