Evaluation of techniques for treating the bleeding wound

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\textbf{Introduction}

The drive to conquer new horizons often results in the neglect of critical review of prevailing medical conduct; in this case, the scientific scrutiny of the essentials of wound treatment. Therefore, we decided to examine methods of urgent bleeding control. Emergency medical personnel are fully familiar with the techniques of manual compression and field bandage dressing. In areas of urban South Africa heavily stricken by trauma, compression over bleeding wounds is achieved by means of a crepe bandage and gauze pads. The technique of compression bandaging, ELastic Adhesive Dressing (ELAD), has been suggested as the preferred solution for the diverse demands of bleeding control from most body surfaces.\textsuperscript{9–11} The purpose of this study was an objective evaluation of these techniques under controlled conditions.

\textbf{Summary}

\textit{Background:} Despite the fact that the urgent control of active bleeding from external body surfaces demands a basic procedure, it is puzzling that this topic has received little if any attention in modern medical research. Elastic adhesive dressing (ELAD) has been proposed for dressing the bleeding wound. \textit{Methods and materials:} Three techniques were compared over a simulated wound in a human model. Pressures generated between the chosen dressing surface and the underlying mock wound’s cutaneous surface, time consumption, convenience, satisfaction and pain were tested for each technique. \textit{Results:} Sixty-eight experiments were performed over nine separate anatomical sites. Average pressures for field dressing, ELAD and manual compression were 33, 88 and 180 mmHg, respectively; these differences in pressure were statistically significant. Manual pressure was equally inconvenient for both patient and caregiver. The more proximal and wider anatomical regions were more difficult and time consuming to compress. The caregivers graded ELAD the highest level of convenience and general satisfaction. \textit{Conclusions:} Field bandage testing reflected its inadequacy in controlling bleeding from most body regions. The results suggest that ELAD may be the hands-free technique of choice. We hope that this article will stimulate further research and elicit evidence on precisely which technique is most suitable for various anatomical location.

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Materials and methods

Intervention

(A) Manual compression was achieved by opening a field bandage over the mock wound and then applying single-handed or bimanual pressure.

(B) The field bandage was applied as commonly instructed, with its strings tied as tight as possible.

(C) The ELAD comprised an elastic ("ace") bandage with adhesive properties. Two such marketed rolls were chosen for use in this experiment and in turn integrated into the compact bandage: COBAN™ (3M Health Care Co., St. Paul, USA), normally used for postsurgical wound covering or PEG brand (Becton Dickinson Co., NJ, USA), commonly marketed for the fixation of injured limbs in orthopaedics. The adhesive roll was attached to an eccentric non-adhesive, absorbent contact pad. Stickiness was achieved via the inherent properties of the fibres that constitute this roll, which have an intrinsic capacity to adhere firmly to their own surfaces but only minimally to hair or skin. This bandage, being only mildly adherent, was easy to open without unwanted sticking to latex gloves, which were donned as would be expected in true-life incidents. For the compression dressing, the non-adhesive, absorbent contact pad was positioned over the area of injured tissue, creating a protruding surface above the wound. The dressing was held in position with one hand while the other hand rapidly wrapped the roll repeatedly around the body surface involved, proceeding with growing tension, again over the desired location, until a firm, tight dressing resulted.

In order to judge whether a rigid, protruding body enhanced pressure where the standard ELAD failed to reach satisfactory pressures, an improvisation was added. A 5 cm × 5 cm × 2.5 cm block of wood was inserted onto the external aspect of the contact pad and then, as with the other bandages, sealed by continuous wrapping.

Body regions

The areas of the body that had to be included by all of the participating teams were the upper arm, thigh, scalp and groin. Optional anatomical locations were the lateral neck (dressed by wrapping the dressing around the contralateral elevated arm or axilla), shoulder (superior, proximal aspect), axilla, and below the knee stump of a volunteering amputee.

Pressure measurement

The designated body regions were each tested separately by a novel pressure-sensitive instrument comprising two discrete components:

1. an air bladder manufactured as a blood-pressure cuff for premature infants;
2. a pressure sensor or transducer acting as a manometer, sensitive to alterations of pneumatic pressure and capable of interpreting registered pressure generated externally over the surface of the cuff into a numerical reading on a LED monitor. The apparatus used was manufactured by ‘Sunx’ (registered trade company), from the DP-Y series, subunit DP-Y27. It consists of an interface of a semiconductor transducer within a moulded case and a Hastelloy C diaphragm in silicone oil and covered by a stainless-steel pressure port. The sensor is specifically marketed for the purpose of measuring accurate pressures within narrow ranges. The unit can measure from vacuum pressure to positive pressure between –98.6 and 100.0 kPa. The device allows display of values in either psi, bar or kgf/cm² units. The units we measured were in kPa, easily converted to mmHg by multiplying by a factor of 7.50. An illuminated numerical display is seen on a LED face. A calibrating pushbutton allows each experiment to begin with a starting value of zero. A plastic pipe leads into the pressure port and out towards the opposite end, where the pipe is attached to the sphygmomanometer bladder. This pipe is sufficiently long to allow ample distance between the observer taking the readings and the operator undertaking the bandaging without hindering the experimentation.

The emergency care provider was asked to behave as if treating active haemorrhage from the designated area with one of the chosen techniques. Readings were taken and recorded from the LED display as dictated by the study design.

Participants

Four separate teams from various ranges of field experience participated in the study. An experienced trauma team employed in a rural area of a security zone; an ambulance crew employed in a major urban area; a military medical unit well trained in the theoretical and training aspects of care of the wounded, but with limited or no practical experience; and a group of first-aid volunteers trained through standard community courses.
The teams themselves provided non-paid volunteers serving as ‘mock-wounded victims’ whose body parts were to be dressed. Each volunteer went through the assessment of all the techniques of bleeding control for each specific anatomical location.

Each of the teams was similarly prepared: each of the three techniques studied was demonstrated and, following a single demonstration, the members felt confident to attempt the experiment without prior experience with ELAD.

**Study structure**

The various methods served as control groups for each other. The first and main part of the study concentrated on pressure readings. The measurements were taken at either 0.5 or 1 min intervals. If fluctuations existed between measurements they were continued for the first 7 min. We also measured the time consumed to the completion of wound treatment (in the case of direct pressure this value has no significance).

Perfusion to the distal limb was examined, where relevant, by manual palpation of the extremity. The participants reported the subjective sensation of pain or suffering due to the application of technique on a visual analogue scale of 1—10. The caregivers answered two separate questions by indicating on a numerical analogue scale the convenience with which the procedure was performed and their overall satisfaction.

**Interpretation of data**

Data from questionnaires was entered on Epi-info 6.01 and analysed using the SPSS statistical package.

**Results**

In total, 68 experiments were performed. Team preparation and adherence to protocol guidelines were satisfactory and equal among the different teams. The results recorded with ELAD, the most unfamiliar technique, were in fact most often those from the first attempt at performing the procedure.

**Time**

Data on the timing of the procedures allowed comparison between the field dressing and ELAD. In a number of experiments using the field bandage, team members abandoned the technique after failing to reach minimally significant pressures.

**Pressures**

Cumulating the data for the various body areas showed that the field bandage generated an average pressure of 33 mmHg (range: 0.82–65 mmHg). Manual pressure exerted an average of 180 mmHg (range: 130–230 mmHg). Elastic adhesive dressing applied 88 mmHg of pressure (range: 44–120 mmHg depending on body site). These differences were statistically significant (Table 2). Irrespective of the technique, the most consistent positive correlation for distal circulatory compromise was with increasing pressures. In no instance was a tourniquet effect witnessed below pressures of 75 mm Hg; this held true across the various body regions examined.

**Pain**

Participants rated their pain sensation after each experiment, disclosing significantly less suffering with methods other than manual pressure.

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**Table 1** Comparison of body regions and time

<table>
<thead>
<tr>
<th>Body part</th>
<th>Time consumed in seconds in order to complete dressing (mean ± S.D.)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groin</td>
<td>108 ± 44</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Scalp</td>
<td>97 ± 43</td>
<td></td>
</tr>
<tr>
<td>Thigh</td>
<td>86 ± 47</td>
<td></td>
</tr>
<tr>
<td>Arm</td>
<td>78 ± 36</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2** Comparison of methods and pressures

<table>
<thead>
<tr>
<th>Method</th>
<th>Pressure (mmHg) (mean ± S.D.)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field bandage</td>
<td>33 ± 32.12</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Manual pressure</td>
<td>179.98 ± 49.34</td>
<td></td>
</tr>
<tr>
<td>ELAD</td>
<td>88.01 ± 44.33</td>
<td></td>
</tr>
</tbody>
</table>
Satisfaction and ease of use

The 16 participating volunteers attested to being overall more satisfied with ELAD, finding this method statistically significantly easier to use than the others Table 3. No conclusions could be drawn for each separate anatomical site because of the small sample size. Fig. 1 graphically depicts the differences in satisfaction between the techniques by body area.

During the experimentation, the Coban roll tore while being stretched and a different unit was needed to complete the application of ELAD sufficient to achieve adequate pressure; this mishap occurred over the scalp, thigh and groin regions, and therefore the PEG version was preferred and employed for these regions. A disadvantage of the PEG roll was that it was relatively more difficult to pull open than the Coban, which therefore delayed the wrapping.

Discussion

Immediate control of acute external haemorrhage in the trauma victim is the most basic of life-saving procedures. The current recommendations as stated in the ATLS course manual American College of Surgeons (1997, p. 29) that ‘Rapid external blood loss is managed by direct manual pressure on the wound … tourniquets should not be used …’, is not based on any established evidence whatsoever. Although training/teaching the various acceptable techniques is universal, to the best of our knowledge no previous study has attempted to evaluate critically the efficacy of any of the practised methods. An exhaustive Medline search on material published between 1966 and 2002 discloses no data on preference between existing procedures. This fact may reflect despair of gaining valuable information from either clinical or even laboratory studies of this challenging topic. In a large meta-analysis of

| Table 3 Overall comparison of satisfaction and patient pain by method (N = 68) |
|-------------------|-----------------|-----------------|-----------------|
| Method            | Patient pain    |                | Satisfaction    |                |
|                   | (mean ± S.D.)   | P              | (mean ± S.D.)   | P              |
| ELAD              | 3.30 ± 2.82     |                | 8.74 ± 1.54     |                |
| Field bandage     | 3.65 ± 3.35     | NS             | 4.53 ± 3.41     | <0.0001        |
| ELAD              | 3.30 ± 2.82     |                | 8.74 ± 1.54     |                |
| Manual pressure   | 6.09 ± 2.98     | 0.002          | 6.43 ± 2.39     | <0.0001        |

Figure 1 Differences in satisfaction between the techniques by body area.
on-scene trauma care, the parameter of haemorrhage control is completely ignored. The realization of drawbacks of current methods should provoke both the development and the promotion of better methods. A solitary recent publication by Calkins et al. evaluated all the known tourniquet systems available on the market, plus two of their own genuine inventions. By timing and pulse measurement of the examined extremity only, they singled out bladder and ratchet systems as the most compact and feasible for use. They themselves advocate the use of some sort of compression for proximal injuries.

The present study has pioneered the use of an instrument suitable for examining pressures induced by various dressing methods. This instrument can equally provide useful information on pressures beneath tourniquets and over various anatomical regions. Likewise, since the method is objective, other researchers may decide to challenge our results with their own skills and teams. Our intention was to include known techniques customarily employed to treat the bleeding wound, but, considering the obvious limitations of the rubber tourniquet over proximal body areas and the immense pain involved when it is used in practice, we decided to forego examining this technique. MAST compression of bleeding limbs has been more or less unanimously abandoned and therefore to examine the pros and cons of this method seemed superfluous. Field dressings are the most commonly found constituent of first-aid kits around the world and are a compulsory part of soldiers’ equipment in most armies.

As would be expected, we have demonstrated that more proximal wounds are more time consuming to dress, regardless of technique. In the context of urgent evacuation it would seem rational to control haemorrhage from these areas by manual pressure upon contact, and only to apply a dressing immediately after loading the patient on to the transporting vehicle.

Aside from wounds in the upper limb and perhaps at time the leg, compression with a field bandage is objectively proved to be unsatisfactory in controlling blood loss from most body surfaces. A further bias that would tend to minimize these differences was produced by instances in which field dressings failed to reach recordable pressures and the caregiver abandoned the procedure; therefore the questionnaires in these circumstances were disqualified, which may explain the diminished, insignificant strength of time differences between ELAD and field dressing. Manual compression generates inconsistent fluctuating pressures though consistently above those demanded (remembering that here only a brief initial period of sustained pressure was examined) eliciting superfluous pain. Lieberman et al. claim that even in the controlled conditions of the operating room the use of the tourniquet, produces pressures in excess of those required to attain adequate haemostasis and so this conduct should be curbed. To date, we have not been able to access any data on the minimal external pressures needed to arrest persistent vascular or soft tissue bleeding. Basic principles of physics suggest that it is reasonable to assume that intravascular fluid will flow towards any area of decreased resistance. Increasing external pressures should increasingly slow blood loss, up to the point of equality between external and ensuing intravascular hydrostatic pressures, when blood loss should cease completely. This is consistent with our observation that normal volunteers with normal blood pressures had compromised distal perfusion when the compressing pressure exceeded 75 mmHg. Thus, we can only postulate that applied pressures in the range 60–90 mmHg, opposing peak arterial pressures, should suffice for the exsanguinating victim, depending on their concurrent blood pressure.

The field bandage completely fails to reach significant pressures for anatomical sites such as the neck, groin, shoulder and axilla. Tourniquets are completely impractical for these areas and manual compression, the most feasible option, requires too great an effort to exert longstanding, steady, pressure. Pressures generated here by the ELAD did not prove completely satisfactory. In these instances, a rational approach may be the application of manual pressure on top of the ELAD, which would make a minor though steady contribution to the required external pressure. Likewise, ELAD may serve as the nearest second best to direct manual pressure when the caregiver tires or becomes exhausted by the immense physical exertion demanded over a long period of time. We did observe a trend that ELAD may be considerably less time consuming after training. This technique, as a hands-free method, must be placed in a separate category from manual compression.

Over the stump, the experimenter chose to apply an additional ELAD over the first, with greater success. Where insufficient pressures were reached with the ELAD in its standard format, the addition of a rigid body on the dorsal side of the pad surprisingly failed to provide any advantage. The resulting pressures remained consistently low, contrary to beliefs that have led to training in this method to improve local pressures.

Damage caused by tourniquets applied at high pressure is mainly attributed to the forces arising at
the edge of the cuff where the pressure gradients are the largest.\textsuperscript{5, 15} It follows that the lower pressures permitted by wider compression methods will be less dangerous to underlying structures such as nerves.\textsuperscript{6} Thus, we can expect less damage from the wider compression band of ELAD than from the narrow rubber tourniquet. As an adjunct to these experiments, we examined the potential of the ELAD to act as a tourniquet and observed completely successful arrest of distal blood flow within 25 and 44 s over the upper and lower extremities, respectively.

We were unable to establish sufficiently forceful correlations among the various individual anatomical sites; this would be the goal of a larger study including more experiments. Concentrating on designated, trained participants may minimize flaws stemming from interindividual variation. Furthermore, precious information might come from experiments with our instrument examining manual compression pressure for a span of 40–60 min in a training session. Volunteers for such a feat are as yet lacking.

The design of this trial, we feel, should serve as a starter for a series of studies, on either human or animal models, to explore the field of compression dressing. Despite its limitations we are satisfied that this study has produced meaningful information and pertinent insights into emergency wound care. Our teams, though optimistic about ELAD, envisage a more ideal device consisting of material that is both non-tearable and easily deployed. Training may improve speed and success. A longer strap can increase pressures by allowing more wrapping and save time where previously a whole new bandage was needed.

**Conclusions**

The primary concern for managing the open wound must be bleeding control. A dressing such as the field bandage fastened by strings is demonstrably cumbersome and inadequate for most body parts. Thus, those depending on its use in an emergency rest on a false sense of security. We conclude that ELAD and manual pressure result in higher pressures than standard dressings. Further study should examine blood loss in animal and human models in order ultimately to establish the efficacy of each method in diminishing the volume lost. The elastic adhesive dressing has growing advantages for wound compression. These preliminary results should be substantiated with a larger sample in order to elucidate specific recommendations for specific anatomical locations. The adoption of a detailed policy should help to improve the prognosis for the trauma victim suffering from acute external bleeding.

**References**