

ORIGINAL RESEARCH



Investigating pressure bandaging for snakebite in a simulated setting: Bandage type, training and the effect of transport

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Abstract

Background: The clinical evidence base for the use of pressure bandaging in snakebite is limited. We aimed to investigate if pressure bandages (PB) generated and maintained presumptive optimal pressures in a simulated setting.

Methods: A total of 96 subjects were recruited, 78 health professionals and 18 from the general public. Participants were asked to apply PB with crepe and with an elasticized bandage without instruction. A paediatric blood pressure cuff attached to a pressure transducer was used to measure the pressure generated. PB application with elasticized bandages was repeated by 36 participants (18 general public and 18 health professionals) with feedback on pressures attained, and reassessment on the sixth subsequent attempt. Pressure was also measured under correctly applied bandages during an ambulance ride.

Results: The median pressure generated under crepe bandages was 28 mmHg (interquartile range [IQR]: 17–42 mmHg) compared with 47 mmHg (IQR 26–83 mmHg) with elasticized bandages, with most subgroups applying the elasticized bandage closer to the estimated optimal pressure (55–70 mmHg). Following training, the median pressure for the 36 participants was 65 mmHg (IQR 56–71 mmHg), closer to the optimal range than initial attempts. On initial bandaging, 5/36 (14%) participants achieved optimal pressure range with elasticized bandages, compared with 18/36 (50%) after training ($P=0.002$). Crepe bandages initially correctly applied did not maintain desired pressure during ambulance transport on urban roads over 30 min. Elasticized bandages maintained pressure.

Conclusions: PB was poorly done by the general public and health professionals. Crepe bandages rarely generated optimal pressures compared with elasticized bandages, but training did improve participants' ability to apply elasticized bandages. PB recommendations should be modified to specify appropriate bandage types.

Key words: *first aid, pressure immobilization bandaging, pressure bandaging, snakebite.*

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Introduction

First aid for snakebite using pressure bandaging with immobilization (PIB) was formally endorsed by the Australian National Health and Medical Research Council in 1979 and has since remained national policy from all health authorities. Nevertheless, the clinical evidence base for its use in humans remains limited to anecdotes and a few published case reports of success in humans.^{1,2} A review of the evidence base for the effectiveness of PIB noted documentation of widespread and ongoing underutilization of PIB and concerns of bandage application, bandage types and the propensity for bandages to loosen during transport.³

The use of PIB for snakebite remains controversial outside Australia, with concerns about confining cytotoxic venoms to the bite site and the possibility that this increases morbidity after certain snakebites.^{4,5} In Australia and Papua New Guinea, snake envenoming mortality and morbidity occur as a result of systemic effects of venoms; morbidity resulting from local effects is rare. For this reason, the Australian PIB, coined 'the Aussie wrap' by the eminent Professor David Warrell, is considered most appropriate for snakebite in Australia and Papua New Guinea and for snakebite with potential neurotoxic envenoming outside this region.⁶

The use of PIB was based initially on studies by Sutherland *et al.* that showed that a firm crepe bandage applied to the immobilized limb of an envenomed, restrained monkey retarded systemic venom movement.⁷ The same investigators judged that a firm crepe bandage generated 55 ± 5 mmHg on a human limb.⁸ Subsequent studies have attempted to assess the potential effectiveness of PIB in humans, using radio-isotopes to mimic venom transport.⁹⁻¹¹

In 1994, it was demonstrated that PIB retarded the movement of radio-labelled macromolecules in the lower limb for pressures of 55–70 mmHg and in the upper limbs for pressures between 40 and 70 mmHg.⁹ That study also found that complete immobilization is a key part of this first-aid technique because even when a subject had effective bandaging, movement invariably led to failure of the first aid.⁹ Therefore, for PIB to be effective the pressure required was considered to be within these ranges and there had to be complete immobilization.

There have been numerous clinical studies of snakebites that have repeatedly shown that PIB uptake and application are poor in patients with suspected snakebites.¹² However, there has been little attention given to whether bandages can be applied by the community

and health-care professionals to produce the appropriate pressure, what is the most effective type of bandage, whether training improves the application of PIB and whether things, such as patient transport, affect the pressure under the bandage. Indeed, two recent papers highlight the confusion around PIB recommendations and its use.^{13,14}

If PIB cannot be applied and maintained with the correct pressure, then it might not be any more effective than immobilization alone. The aims of the present study were:

- To determine if bandages could be applied at the presumptive correct pressure by a range of populations
- To compare the pressures generated by different, commonly available bandage types, with subsequent focus on crepe and an elasticized sports bandage
- To assess whether training improved the chance of elasticized sports bandages being applied at the presumptive correct pressure
- To determine the effect of transport on initially correctly applied bandages

Methods

The study was a human volunteer study where subjects were asked to apply a pressure bandage to a human lower limb in a simulated setting of a snakebite. The outcome for the study was the pressure generated on the limb by the application of the bandage.

Posters advertising the study were displayed and information was circulated via email through health care-related networks to recruit volunteers for the study. A total of 96 participants, 78 health-care workers and 18 people from the general public, were recruited for the main part of the study comparing crepe and elasticized bandages (ACE, BD, North Ryde, NSW, Australia). Health-care workers were defined as undergoing a degree or training programme to be able to care directly for patients, including final-year medical students. All participants were initially asked to bandage a lower limb and were randomized to either crepe or elasticized sports bandage for their first application. Results are displayed according to prior qualification.

Thirty-six of the participants, divided into six subgroups, were also enrolled in an additional study arm to determine if training could improve bandage technique. The six groups were: medical practitioners (intern or higher), nurses, ambulance officers, snake handlers, members of the general public who lived in metropolitan

areas and members of the general public who currently, or had in the past, resided in rural areas. Residing was defined as living for 10 years or more. These 36 (6 health professionals from each of the 3 groups, 6 snake handlers and all 12 participants from the general public) underwent further training to assess whether teaching and practice improved application of elasticized bandages.

Before the participant studies and to initially assess different types of bandages and determine the appropriate choice for the further investigations, various commercially available bandages were applied by the same person to a dummy arm (Adult IV training arm, Laerdal Medical, Oakleigh, Victoria, Australia) and a human leg on 30 occasions for each different material. Based on these results, 15 cm elasticized bandages were chosen as the best material (including cost considerations) to compare with traditional crepe bandages. As the elasticized bandages outperformed crepe in the studies on a dummy arm and human leg, they alone were chosen to be used in the training arm of the study.

Initially, all 96 participants were asked to perform two bandage attempts on a leg. For one attempt, two 15 cm elasticized bandages were provided and, for the other attempt, two 15 cm crepe bandages were supplied. These attempts were completed without prompting as to method or tension. If only one bandage was used or only partial coverage was achieved, this was recorded. If a participant attempted a tourniquet or did not bandage over the bladder where pressure was measured, they were corrected and allowed a second attempt. Participants were randomly allocated to either an elasticized bandage or crepe first using sealed sequential envelopes and computer-generated blocks of four. Two female subjects weighing 55 and 65 kg were used as simulated patients for all bandaging. The participant was blinded to the reading on the pressure transducer while bandaging.

For the 36 participants trained with further bandage applications, the requirements of the technique were explained and then two elasticized bandages were used on the leg over four further attempts. Before each subsequent attempt, participants were told the pressure reading. This training method was simple and, with minimal equipment, could be incorporated into first-aid training in a group or individual setting. Participants were then assessed on their sixth attempt using the same pressure outcomes. Throughout the course of the experiment, any bandaging that stopped short of covering the entire limb was noted and recorded.

In the final part of the study, the effects of vehicle transport on ambulance-issue crepe PIB were investigated using an off-duty St John Ambulance Vehicle and an experienced paramedic. In this case, four digital pressure transducers were used. One was attached to each leg of two subjects. Subjects were first bandaged to achieve pressures within the optimal range while lying in the back of an ambulance. The ambulance was then driven for approximately 30 min on sealed roads for each run and the pressure recorded every 5 min. Bandages were replaced between runs. Crepe bandages were applied six times, with and without splinting and, for comparison, elasticized bandages were applied on two occasions.

The pressures generated by the bandages were measured using a paediatric blood pressure bladder attached to the standard inflation bulb and a Druck 705 pressure transducer (Melrose, MA, USA). In the initial studies on a Laerdal adult i.v. arm, the bladder was taped approximately 50 mm below the elbow crease on the front lateral side of the arm (in anatomical position). On a leg the bladder was taped approximately 75 mm from the knee cap on the lateral front of the lower leg. The tubes of the bladder were secured at the wrist or ankle for the arm and leg, respectively. The bladder was inflated so that pressure read 1 or 2 mmHg and the transducer zeroed so, although air was contained in the bladder this gave no pressure reading. Minimal air in the bladder kept it as close to the normal limb contour as possible. Three additional pressure transducers (RS 232 manometers - model 8252, SensorsONE, Rutland, UK) were sourced for the ambulance recordings.

The main outcome measure was generating a bandage pressure within an optimal pressure range, defined as 40–70 mmHg on the upper limb and 55–70 mmHg on the lower limb.^{9–11} The bandage should cover the length of the limb.⁷

Analysis

Data were analysed by comparing the proportion generating an adequate pressure between each group at first and final attempts. Pressures were reported as medians and interquartile ranges (IQR) and comparisons were made with non-parametric tests.

Results

The initial comparison of various commercially available bandage types on the lower limb found that

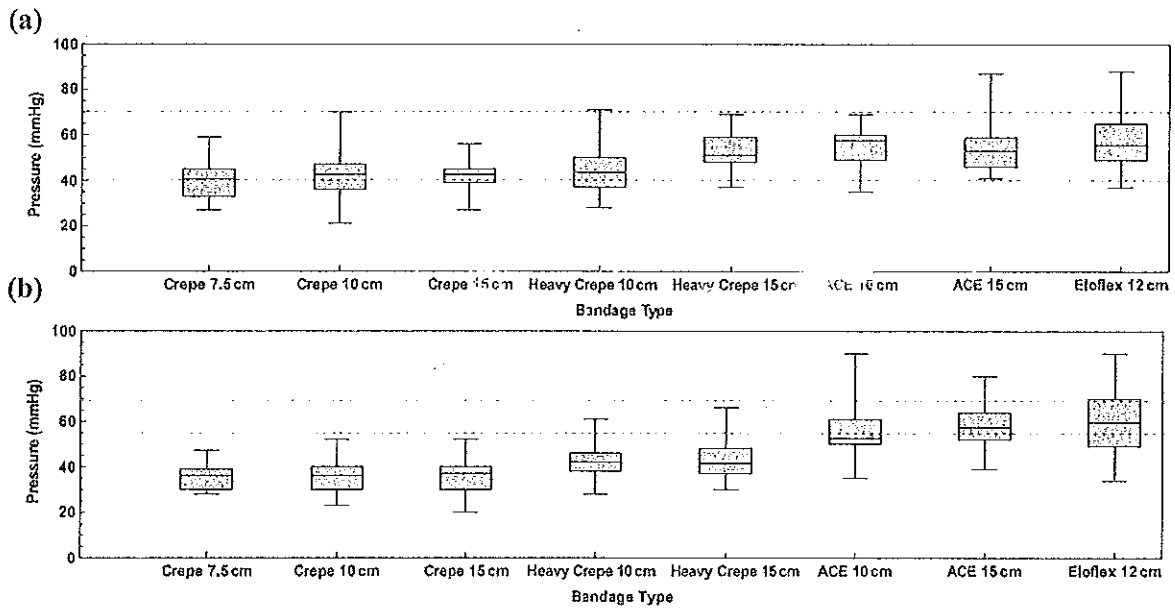


Figure 1. Pressures generated by a single operator on 30 different occasions for each bandage type using a dummy arm (a) and a human leg (b).

standard crepe bandages consistently generated pressure below the optimal range, with a mean pressure of 36 mmHg (SD 8 mmHg), while the elasticized bandages (ACE) appeared to be the most effective bandage material, generating a pressure of 59 mmHg (SD 9 mmHg) (Fig. 1). There were similar results for the upper limb (Fig. 1).

Of the 96 participants, 95 applied both a crepe and elasticized bandage to the lower limb. The median pressure generated for the crepe bandage was 28 mmHg (IQR 17–42 mmHg) compared with 47 mmHg (IQR 26–83 mmHg) with the elasticized bandage. Of the trained health-care workers participating in the study, 13 out of 78 (17%) achieved the correct pressure at the first attempt. According to the self-reported questionnaire, 22 of the 78 (28%) had previously treated snakebite in either a hospital or emergency responder setting. One participant dropped out after attempting to apply a tourniquet and there were eight others who had to be corrected before the pressure could be judged because they either attempted a tourniquet or only bandaged the ankle at the first attempt. Twenty-four participants bandaged only to the knee in one or more attempts before training. The range of pressures for all 95 participants for both the crepe and elasticized bandages is shown in Figure 2.

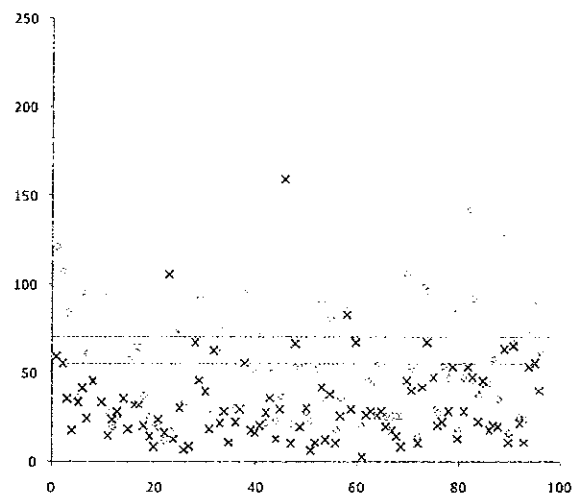


Figure 2. Scatter plot of bandage tensions generated by all participants. (○) 1st ACE; (×) 1st crepe.

The initial pressures for crepe and ACE bandages by the six subgroups of participants subsequently trained is illustrated in Figure 3a, showing that in most groups the elasticized bandage was more likely to be applied in the optimal pressure range. Following training with

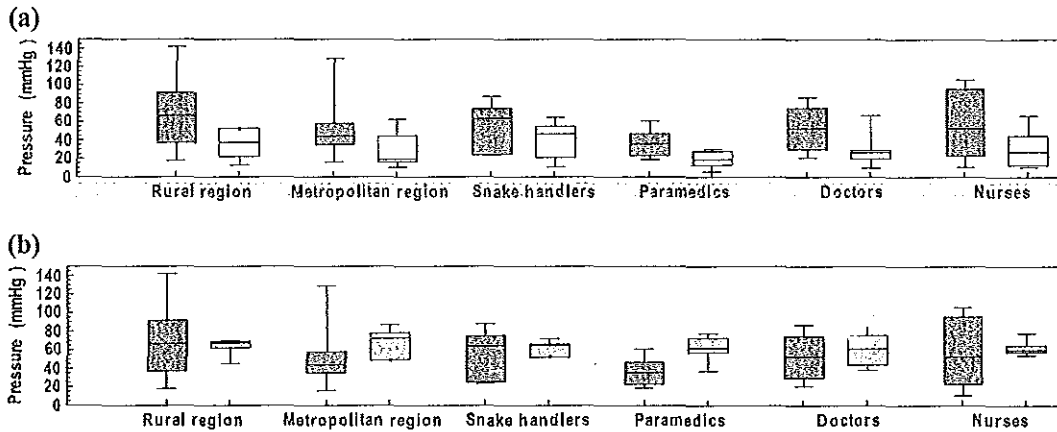


Figure 3. Bandage pressures in the six different subgroups for the elasticized bandage (ACE) (dark) and crepe (light) on their initial attempt (a) and before training (dark) and after training (light) (b).

the elasticized bandages, the median pressure for all 36 participants was 65 mmHg (IQR 56–71 mmHg), which was closer to the optimal range than the initial attempts that generated a median of 47 mmHg (IQR 27–75 mmHg). On initial elasticized bandaging, only 5/36 (14%) participants were able to generate a pressure in the optimal range compared with 18/36 (50%) after training ($P=0.002$) (Fig. 3b).

Bandage pressures were measured during a 30 min ambulance trip and demonstrated that all crepe bandages (with or without splinting) did not maintain pressure after an initial bandage was applied at the correct tension (Fig. 4). Conversely, in two subjects with elasticized bandages without splints pressure was better maintained (Fig. 4).

Discussion

Overall, pressure bandaging ability was poor in both the general public and in health professionals. Whether application was being attempted on a mannequin arm or on a human lower limb, the traditionally recommended crepe bandages consistently failed to achieve the appropriate pressure range. Elasticized bandages were shown to be more effective and training improved participants' ability to apply this type of bandaging. Even when the correct initial pressure was achieved with crepe bandaging and immobilization was secured, the transport study suggested that adequate pressures could not be maintained over a relatively typical journey to hospital.

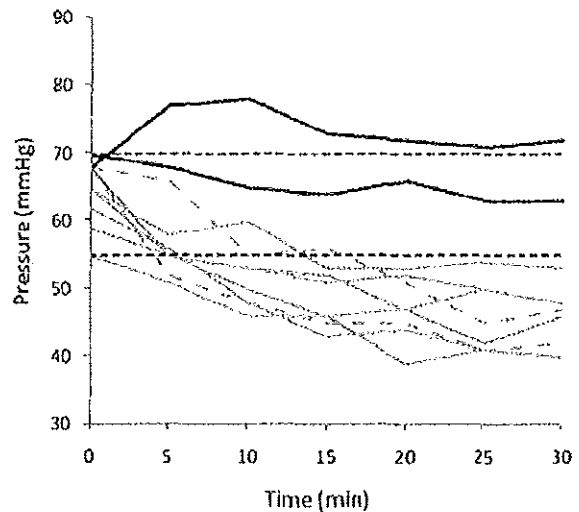


Figure 4. Changes in pressure under the bandage over time during a 30 min ambulance ride for crepe bandaging without splinting (dashed line), crepe bandaging with splinting (grey line) and elasticized bandaging (black line). Estimated optimum pressures are indicated. (---) Crepe unsplinted; (---) crepe splinted; (—) elasticized bandage unsplinted.

These studies were limited to simulated scenarios; it is not ethical to recreate the panic of snakebite. It is possible that the stress of the situation would mean that bandaging may be applied tighter, or that the correct technique would be forgotten altogether. In addition, we could not determine pressures over the whole limb with this technique, because measurements were restricted to

the area of the bladder under the bandage. This could explain why on one occasion during ambulance transport the pressure rose under one of the elasticized bandages (see Fig. 4); as pressure was measured below the knee, we might have exceeded the optimal pressure above the knee and created a venous tourniquet. This bandage caused significantly more discomfort than any other bandage applied in the simulated ambulance study. No participant applied bandage created undue discomfort in these studies, except on the occasions when a participant deliberately applied a tourniquet, believing this to be the preferred method.

It is important to state that to date there is only one study that specifically aimed to define optimal pressures for PIB in humans and, for our studies, we have used those values published by Howarth *et al.* for comparison of bandaging pressures.⁹ Further research might change these currently recommended bandage tensions and hence our data must be considered in the context of the assumption that bandages maintaining pressures in this range are effective.

Suspected snakebite is common at Royal Darwin Hospital^{15,16} and our study involved members of the most snake-aware subsets of the population. Participants in the study included members of the general population from rural areas in the Northern Territory who live with snakes as a relatively common neighbour; local ambulance officers who frequently treat suspected snakebite cases; and snake catchers and handlers where being bitten by the reptiles being caught or in their care is an occupational hazard. If the study had focussed on a different subset of the population, results might have differed.

There is controversy as to whether crepe bandages work at all. There were several differences between the early animal models of pressure immobilization and the true snakebite scenario. The monkeys used in the original research weighed between 2.5 and 3 kg.^{7,8} Throughout those experiments, three limbs of each monkey were immobilized on a frame, leaving only one limb free for the application of first aid.⁸ Immobilization of all limbs is not possible in life and movement of a patients' free limbs has an influence on the effectiveness of first aid in the clinical scenario.⁹ The controlled conditions and size differences might explain why crepe bandages worked so effectively in the original monkey trials yet in our study did not produce the appropriate pressure. Furthermore, although Sutherland *et al.* estimated that a firm crepe bandage generated 55 ± 5 mmHg and was effective,⁸ a study by Anker *et al.* found that a pressure bandage with immobilization failed at every attempt to

retard labelled mock venom spread in humans.^{10,11} As an alternative to pressure bandaging, Anker *et al.* developed the 'Monash Method' that used a pressure pad under a firm bandage. A prospective study in Burma measuring plasma venom concentrations before and after release of the compression pad first aid showed objective evidence of benefit from this method.¹⁷

The relatively affordable (AUD 5.15 at the time of the study) elasticized bandage shows promise in these preliminary studies. Not only was it possible to attain the desired pressure range, but the ambulance study suggested that, in comparison with crepe bandages, these pressures might be maintained until definitive hospital treatment can be accessed. However, to have a success rate of 50% immediately after training is not, in the authors' opinions, an ideal result and supports calls for further research into first-aid training as well as the parameters that optimize the potential effectiveness of PIB.¹³

Although snake handlers appeared to have a greater understanding of bandaging for snakebite and several of the snake catchers enrolled taught this method to others, overall only 16 of the 36 (44%) elasticized bandage attempts by the snake catcher group achieved correct pressures.

Previous studies have documented that education about PIB in Australia appears to have been inadequate, with people commonly not applying splints, or even neglecting any attempt at first aid at all.^{12,18} Our study suggests that, even by strictly following the current National Health and Medical Research Council /Australian Resuscitation Council guidelines for snakebite, first aid with PIB using bandages currently available in many first-aid kits might actually not enable Australians to alter the outcome of a bite beyond the potential benefit of immobilization itself. On a more positive note, intensive training did improve performance with elasticized bandages. Although not everyone succeeded in achieving presumptive correct pressures following training, they did get closer to the mark in the majority of cases. It was not within the scope of the study to look at people a period of time after the training to see if they had retained the knowledge gained. It should be noted that many participants had completed first-aid courses but had forgotten much of the detail of the technique before the study.

Complacency surrounding snakebite first aid appears to be the accepted state of affairs in Australia. First aid for snakebite has not been explored to a depth that provides a strong evidence base for an effective first-aid technique and there are serious concerns about the

effectiveness of PIB in real snakebite cases. Education and training have not been designed or maintained at a level that would render the majority of the population able to execute the nationally adopted technique of PIB. Furthermore, bandage materials and the technology of PIB have not been re-evaluated for almost 30 years.

It seems logical that applying first aid promptly after a snakebite might protect the victim from venom absorption and, therefore, envenoming if both correct pressures are obtained and immobilization is strictly adhered to. We recommend that PIB should continue to be promoted as the standard for Australia. However, we do recommend that immediate changes are made to written guidelines in Australia noting the inadequacy of standard crepe bandages and that elasticized bandages are superior in obtaining and maintaining adequate pressures.

Finally, prospective multicentre studies of snakebite with quantitative plasma venom concentrations will hopefully better elucidate the true effectiveness of PIB or alternative techniques, such as pressure pads. Prospective studies will also help define the limitations of timing of application, and determine the optimum types of bandage materials to use and the optimum pressure to be achieved and maintained.

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Competing interests

GKI is an assistant editor for the journal.

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