Exsanguination of the upper limb in healthy young volunteers

L. Blond, J. L. Madsen

From Amager Hospital and Hvidovre Hospital, Copenhagen Hospital Corporation, Denmark

Using a scintigraphic technique based on an autologous injection of $^{99m}$Tc-labelled erythrocytes, we have evaluated the efficiency of different exsanguination procedures in the upper limb of ten healthy male volunteers. The methods were elevation alone, the use of the Esmarch bandage or a gauze bandage, the Pomidor roll-cuff, the squeeze method and the Urias bag.

The various procedures gave the following median percentage reductions of blood volumes: elevation for 5 seconds 44%, 15 seconds 45%, 30 seconds 46%, 60 seconds 46% and 4 minutes 42%, the Esmarch bandage 69%, a gauze bandage 63%, the Pomidor roll-cuff 66%, the squeeze method 53%, and the Urias bag 57%. With regard to elevation alone no significant differences were found. All the external methods were significantly more effective than elevation alone.

Overall, the squeeze method was found to be the best method of exsanguination before inflation of a tourniquet, because it is effective, fast, practical and inexpensive.

Received 16 August 2001; Accepted after revision 17 November 2001

It is generally accepted that operations on the limbs are made easier by the use of a tourniquet. In order to reduce the amount of blood in the limb it is exsanguinated before the tourniquet is inflated. In a recent study we have compared different techniques of exsanguination of the lower limb using a scintigraphic method. Contrary to previous studies by Lister (in 1909) and Warren, Hardiman and Woolf, who found that elevation for four or five minutes was sufficient. As others have shown, methods of external compression are significantly more effective than the use of elevation alone. The scintigraphic method which we used is both more precise and physiological than plethysmography for the measurement of changes in the blood volume in the limbs.

In this study we have evaluated various methods of exsanguination of the upper limbs including elevation alone, the use of bandages, the squeeze method, the Urias bag and elevation for longer than 30 seconds.

Subjects and Methods

Ten healthy male volunteers with a mean age of 26 years (20 to 34), a mean height of 186 cm (174 to 202) and mean weight of 86 kg (74 to 104) participated in the study. The local Ethical Committee approved the study and the subjects gave written informed consent.

The method for the evaluation of changes in the blood volume was based on the autologous injection of $^{99m}$Tc-radiolabelled erythrocytes and the use of a pneumatic tourniquet. Each subject was placed supine with the arm on a gamma camera. A one-minute scintigram of the forearm was obtained before and after exsanguination. In order to have a consistently reproducible position of a region of interest (ROI) for subsequent integration of radioactivity a $^{57}$Co source was placed 3 cm distal to the medial epicondyle of the humerus. For the ROI we used the smallest rectangle which included the right hand and the part of the right forearm distal to the marking. The same ROI was used for all measurements in each subject. Examples of scintigrams are given in Figure 1. The percentage reduction of blood volume was then calculated from counts obtained before and after exsanguination.

The following types of exsanguination procedures were tested: elevation alone, the use of the Esmarch bandage, a gauze bandage, the Pomidor roll-cuff (Pomidor AB, Varnamo, Sweden), the squeeze method, and the Urias bag. For elevation the examiner lifted the arm to a vertical position for 5, 15, 30 and 60 seconds and 4 minutes, respectively. After exsanguination, a 14 cm pneumatic cuff placed on the upper arm was inflated to a pressure of 200 mmHg. Both the Esmarch and gauze bandages were applied using an
overlap of a half width. The pneumatic cuff was omitted when the Pomidor roll-cuff was used because it also acts as a tourniquet when kept in place by two rubber wedges. The Pomidor roll-cuff was used according to the recommendations of the manufacturer in that the size of the cuff was chosen in relation to the circumference of the upper arm and the cuff was inflated to a pressure of 120 mmHg before application. The squeeze method is a hand-over-hand procedure on the elevated arm starting with a squeeze of the examined hand and quickly proceeding proximally, displacing the volume of blood into the upper arm proximal to the tourniquet. The Urias bag is an inflatable arm splint intended for stabilisation of fractures as an emergency procedure. The splint was inflated with compressed air to a pressure of 200 mmHg. The tourniquet was then inflated and the splint deflated and removed.

After the cuff was inflated the arm was instantly re-aligned on the gamma camera and a one-minute scintigram was obtained. The tourniquet was then deflated and in order to ensure that the phase of hyperaemia had finished, five one-minute scintigrams were obtained before the next exsanguination.
procedure. All ten methods of exsanguination were performed on the ten subjects in random order, by drawing lots. The time taken for the application of external compression was recorded.

**Statistical analysis.** Friedman’s test was used to compare the median values of the results obtained from the different procedures. A value of $p < 0.05$ was considered to be significant in all tests. All tests were performed as two-tailed.

**Results**

Figure 2 gives the results of the different exsanguination procedures. With elevation alone, no significant difference was found between the results ($p < 0.26$). All the external methods were significantly more effective than elevation alone ($p < 0.002$).

The mean (quartiles) time taken for the application of the various exsanguination procedures was as follows: Esmarch 61 (59 to 63), gauze 67 (59 to 75), Pomidor roll-cuff 13 (11 to 15) and Urias bag 58 (55 to 67).

**Discussion**

Previously, we have used a scintigraphic method for evaluating the effect of different methods of exsanguination on the lower limb. Exsanguination after 30 seconds of elevation was 45% in studies on both the upper and lower limbs and the efficiency of the Esmarch bandage was 64% in the lower limb compared with 69% in the upper limb. Our studies indicate that exsanguination of the upper and lower limbs is determined by the same physiological mechanisms.

As in the study on the lower limb we have shown that external methods give more effective exsanguination than elevation alone. This finding is supported by the results of previous studies. We unexpectedly found no significant difference between elevation for five seconds and that for longer. This indicates that elevation for five seconds is sufficient for presurgical exsanguination. For the lower limb we found elevation for 30 seconds to be as effective as that for longer. This was the shortest time tested and when planning that study we did not think that elevation for less than 30 seconds would be effective.

The time taken for the application of the various external methods showed significant differences. Thus, the Pomidor roll-cuff took the least time whereas application of the Esmarch and gauze bandages and Urias bag was more time-consuming. This agrees with our findings for the lower limb. The Esmarch bandage was found to be the most effective, but application is time-consuming and sterilisation is difficult. Both the Esmarch and the gauze bandage may be contraindicated if a fracture is present or if the skin is delicate. The Urias bag is impractical; it takes time to apply and is not effective. The squeeze method is the method of choice, although it is not quite as effective as other external methods, but it is fast, practical and inexpensive.

The study was supported by the Foundation for Promotion of Medical Science; ‘A. P. Møller and wife Chastine McKinney Møller Foundation to Public Aim’. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

**References**