# Exsanguination of lower limbs in healthy male subjects

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**ABSTRACT – Gamma camera technique was used to assess the effectiveness of various exsanguination methods in 12 healthy male volunteers given an autologous injection of 99mTc-labeled erythrocytes. The methods used included elevation alone, Esmarch bandage, gauze bandage, and the Pomidor roll-cuff. The median times spent on use of these methods were: Esmarch 85 sec, gauze 104 sec, and Pomidor roll-cuff 18 sec. The various exsanguination methods caused a median percentage reduction in regional blood volume of the lower limbs: elevation 1/2 minute 45%, 1 minute 45%, 2 minutes 42%, 4 minutes 44%, 6 minutes 43%, 10 minutes 44%, Esmarch bandage 64%, gauze bandage 62%, and Pomidor roll-cuff 61%. No statistically significant differences were found between the elevation procedures. The external methods were more effective than elevation alone ($p < 0.001$).**

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Although exsanguination is a routine method in most orthopedic departments, only a few studies have dealt with this topic. Sir Lord Lister (1909) emphasized the importance of elevation and, after some observations, he recommended 4 minutes of elevation before applying of a tourniquet. However, DiStefano et al. (1974) in a plethysmographic study, noticed that a maximum reduction in blood volume after elevation seemed to occur even after 20 seconds with no noticeable change thereafter. Subsequently, in another plethysmographic study, Warren et al. (1992a) showed that optimal duration of elevation was 5 minutes. Apart from elevation, many methods for exsanguination have been suggested, all based on external compression (Esmarch 1873, Winnie and Ramamurthy 1970, Burchell and Stack 1973, Rhys-Davies and Stotter 1985, Colville and Small 1986, Löfqvist 1988).

The Esmarch bandage is generally thought to provide the most effective exsanguination (DiStefano et al. 1974, Rhys-Davies and Stotter 1985, Colville and Small 1986, Fancourt-Smith et al. 1990, Marshall et al. 1994). Previous studies on changes in local blood volumes in limbs have been based on plethysmographic methods . In this study, we used a new scintigraphic method to evaluate the effect of ordinary procedures for exsanguination of the lower limb before surgery (Blond and Madsen 2000).

## Subjects and methods

12 healthy males subjects with a mean age of 29 (24–39) years, mean height of 179 (173–189) cm, and mean weights of 79 (61–91) kg participated in the study. All had normal blood pressure. The method for evaluating changes in blood volumes was based on the autologuous injection of 99mTc-radiolabeled erythrocytes and the use of a pneumatic tourniquet (Blond and Madsen 2000). The median radioactivity was 737 MBq. Each subject was placed supine on a horizontal inflexible bed with the lower leg aligned in a frame. Using gamma camera technique, a one-minute scintigram representing the lower leg and foot was taken before and after the exsanguination (Figure 1). To ensure reproducibility of the position of a region of interest (ROI) for subsequent integration of radioactivity, a 57Co source was placed 5 cm distal to the proximal demarcation of the right tibia. As ROI we used the smallest rectangle that included the

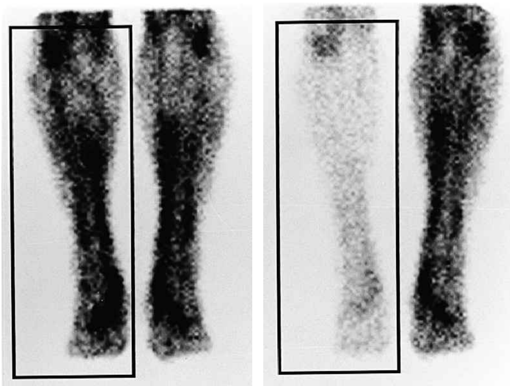

Figure 1. An example of a 1-minute scintigram of the lower limbs of a 25-year-old man obtained by 99mTc-radiolabeled erythrocytes showing the limbs from an anterior projection before and after an Esmarch exsanguination of the right limb. The frame represents the region of interest. The percentage reduction in blood volume, calculated from counts obtained before and after the exsanguination, was 61% here.

right foot and that part of the right crus distal to the marking. The same ROI was used for all measurements in each subject. The percentage reduction in blood volume was then calculated from counts obtained before and after the exsanguination.

The following exsanguination method were evaluated: elevation, Esmarch bandage, Pomidor roll-cuff (Pomidor AB, Varnamo, Sweden), and gauze bandage.

Elevation was done by the examiner who raised the limb to 60 degrees for half a minute, 1 minute, 2 minutes, 4 minutes, 6 minutes, and 10 minutes. The external methods were done with the limb raised to 60 degrees. After exsanguination, a 14 cm wide pneumatic cuff mounted on the thigh was inflated in a few seconds to 300 mm Hg. The pneumatic cuff was omitted when the Pomidor roll-cuff was used, because it also acts as a tourniquet when kept in place with two rubber wedges. The roll-cuff was used in accord with the recommendations of the manufacturer—i.e., the cuff size was chosen in relation to the circumference of the thigh and the cuff was inflated to a pressure of 120 mm Hg before use. Both the Esmarch and gauze bandages were applied using half of the width overlap. With the cuff inflated, the limb was realigned on the gamma camera and a one-minute scintigram was taken. The tourniquet was then deflated and in order to ensure that the phase of hyperemia was over, 12 one-minute scintigrams were taken before the next exsanguination. All 9 types of exsanguinations done in the 12 subjects were performed in random order, using the drawing lot principle. The time taken to apply and remove the external methods was noted.

### *Statistics*

Friedman's test was used to compare the median values of the various exsanguination methods. A value of $p < 0.05$ was considered significant in all tests. Two-tailed tests were used. The data were analyzed with STATISTICA software package.

The local committee on ethics in Copenhagen approved the study. The subjects gave their written informed consent.

## Results

The hyperemia phase lasted less than s4 minutes (median and quartiles 1.003 (0.963–1.057)) versus the opposite limb.

The median times for use of the exsanguination methods were: Esmarch 85 (81–94) sec, gauze 104 (90–107) sec, and Pomidor roll-cuff 18 (15–21) sec. The Pomidor roll-cuff took less time than the Esmarch bandage and gauze bandage ($p = 0.009$).

The various exsanguination methods resulted in the following median percentage reductions in regional blood volume in the lower limbs: elevation 1/2 minute 45%, Esmarch bandage 64%, gauze bandage 62%, and Pomidor roll-cuff 61%. For more details, see Figure 2.

As regards the results of elevation alone, no significant differences were found between the various durations of elevation ($p = 0.2$). All the external methods were more effective than half a minute of elevation ($p < 0.001$). No significant differences were found among the Esmarch bandage, gauze bandage and the Pomidor roll-cuff.

## Discussion

The method we used with autologous injection of 99mTc-radiolabeled erythrocytes evaluated changes in blood volume in limbs (coefficient of variation: within subjects 6%, between subjects 14%) more

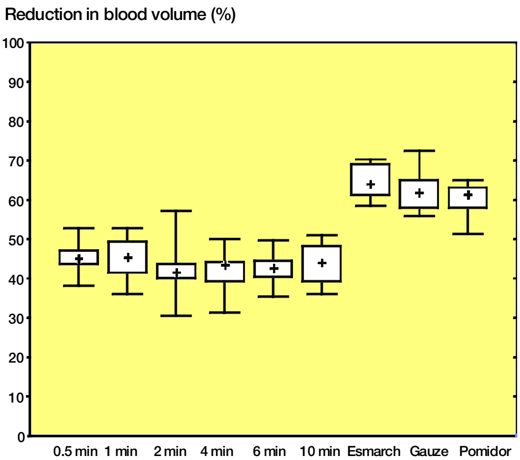


Figure 2. Results of various exsanguination methods in 12 subjects expressed as median (+), range and interquartil (box) percentage reduction in blood volume calculated from counts before and after the exsanguination.

precisely than other plethysmographic methods (Blond and Madsen 2000). It is also a more physiological approach for exsanguination.

We found that external methods induce more effective exsanguination than elevation alone, as reported by others (DiStefano et al. 1974, Rhys-Davies and Stotter 1985, Fancourt-Smith et al. 1990). As regards exsanguination with elevation alone, we found no significant difference between half a minute of elevation and a longer elevation time. This does not accord with Lister's (1909) and by Warren et al.'s (1992a, b) findings but is in the line with the observation of DiStefano et al. (1974) and Notcutt (1978). The discrepancy between ours and those of Warren et al. (1992a, b) may be methodological. Warren et al. (1992a, b) used a strain gauge plethysmographic method that indirectly estimates changes in blood volume since it measures only changes in the circumference of a limb. We believe that some of the interstitial fluid is drained when a limb is raised for more than a few seconds, and such drainage is probably the reason why the circumference of the leg continues to diminish for more than 5 minutes. The problem of stasis, which has previously been shown to occur when the lower limb is elevated to 90 degrees as a result of obstruction in the venous outflow (Warren et al. 1992b), does not seem to occur when using 60 degrees of elevation as in this study.

The oldest subject in our study was 39. To our knowledge no study has addressed the dynamic changes of the venous system in relation to age, gender or vascular diseases. However, it seems likely that some changes can occur, but how this may influence the exsanguination is unclear. Our subjects did not receive any anesthetic, which is common with the use of a bloodless field. We do not know whether this affected our findings.

We regret not to have included an elevation time shorter than half a minute in our study design, because it remains uncertain whether even shorter elevation times are sufficient for optimum exsanguination.

The fact that half a minute of elevation for exsanguination is as effective as longer elevation should change the practice in operating rooms when using elevation alone for exsanguination. A common practice is to inflate the tourniquet immediately after use of antiseptics, since the limb has just been raised for several minutes and has been regarded as optimally exsanguinated. We have learned that this is wrong and in order to minimize the tourniquet time, we believe that the inflation of the cuff should be postponed until the surgical cover has been applied and the surgeon is ready to exsanguinate. If a more effective exsanguination is required one of the external methods can also be used. The times taken for the various external methods differed. More than one minute was spent on putting on the Esmarch bandage, whereas the Pomidor roll-cuff may be putting on very quickly. The Esmarch and gauze bandages are not only time-consuming (O'Hara et al. 1991), but should not be used in the event of a fracture; they can damage the skin, because they induce torsional andlongitudinal shearing stresses (Hallet 1983, Marshall et al. 1994). However, none of the young healthy subjects in our experiment complained of pain when we used these bandages. Furthermore autoclaving the Esmarch bandage is troublesome (Asirvatham et al. 1990, O'Hara et al. 1991). In our experience, the Pomidor roll-cuff is easy to handle and gives fast, good, and constant exsanguination. It also allows placement of the surgical cover more proximal than normal, since the cuff is sterile, gives more freedom to move the leg and see the alignment. However, it has the disadvantage that when reperfusion is needed during an operation, the cuff must pass the operating field.

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