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Journal of Hand Surgery (European Volume) 2008; 33; 475 originally published online Jun 25, 2008;
DOI: 10.1177/1753193408090123

JHS(E)

The Journal of Hand Surgery (European Volume, 2008) 33E: 4: 475–477

CLINICAL CONSEQUENCES OF DIFFERENT EXSANGUINATION METHODS IN HAND SURGERY. A DOUBLE-BLIND RANDOMISED STUDY

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A randomised trial was performed in 100 patients in order to evaluate the effectiveness of three commonly used methods of exsanguination (simple elevation, squeeze method and Esmarch bandage) in a clinical setting. The quality and quantity of the exsanguination was evaluated every 5 min by the surgeon and the amount of oozing was observed. Although there was no significant difference between squeezing the arm and Esmarch bandaging, both resulted in significantly better exsanguination than simple elevation. In 22 out of the 100 patients, a small amount of ooze was observed. The oozing was observed significantly more frequently in the patients exsanguinated by simple elevation.

Keywords: exsanguination, tourniquet, ooze, hand surgery, bloodless field

Several different methods of exsanguination are used in hand surgery and no consensus exists as to which is best (Burchell and Stack, 1973; Colville and Small, 1986; Esmarch, 1873; Harris et al., 2002), though experimental studies have found that Esmarch bandaging is the most effective (Alshawi and Scott, 2004; Blond and Madsen, 2003a, b; Fancourt-Smith et al., 1990; Harris et al., 2002). However, Esmarch bandaging is time consuming and has potential side effects, so other methods such as simple elevation or "hand over hand squeezing" (the squeeze method) are widely used. Blond and Madsen (2003a, b) estimated median percentage reductions of blood volume of 44% after elevation for 5 s, 53% with the squeeze method and 69% when an Esmarch bandage was applied (Blond and Madsen, 2002). In a clinical study, Colville found the hand over hand method (squeeze method) ideal according to the surgeon's subjective evaluation after the operation (Colville and Small, 1986).

Previous studies (Blond and Madsen, 2003a; Furlow, 1971; Klenerman and Crawley, 1977; Santavirta et al., 1978; Spira et al., 1965) have identified that some blood passes under the tourniquet into the arm through bone marrow vessels. However, there are very little clinical data available and the clinical consequence of this has not been evaluated.

The aim of this study was to compare the effectiveness of the three most widely used methods of exsanguinations in hand surgery (simple elevation, the squeeze method and Esmarch bandaging).

PATIENTS AND METHODS

The study was conducted between January 2005 and July 2006 in the Hand Section of Orthopaedic Department, Gentofte Hospital of Copenhagen. The local Committee on Ethics in Copenhagen approved this study, which was done in accordance with the recommendations of the Declaration of Helsinki. Patients undergoing hand surgery under either general anaesthesia or brachial block anaesthesia, with an expected operation time of more than 20 min, were invited to participate and 100 were enrolled having given informed consent. Randomisation to the three groups was by the sealed envelope technique.

Group 1 (34 patients) was exsanguinated by high elevation with the arm vertical for 5 s. Group 2 (32 patients) was exsanguinated by the squeeze method, viz. hand over hand squeezing of blood out of the limb, starting distally and moving proximally with the arm elevated. Group 3 (34 patients) was exsanguinated with a sterile Esmarch bandage. Both the randomisation and the exsanguination procedure were done in the operating room with the surgeon absent, in order to secure double-blinding.

Patients with a history of vascular disorders or with delicate skin, for which use of an Esmarch bandage would be contraindicated, were excluded.

A 12 cm-wide cuff was used routinely and the tourniquet pressure was set to 100 mmHg above each patient's systolic blood pressure (Crenshaw et al., 1988; Moore et al., 1987; Newman and Muirhead, 1986; Van Roekel and Thurston, 1985).

All exsanguinations were performed by the same experienced nurse. Patients' age, height and blood pressure, the tourniquet pressure and the time from its inflation to the start of the operation and the duration of the operation were all recorded. All the evaluation

procedures were performed by the same experienced specialist in hand surgery.

In the first minutes of each operation, both the quality and the quantity of the exsanguination procedure were evaluated separately with a visual analogue scale (VAS – 0–100 mm). The quality endpoints "0" indicated that the operative field could be clearly seen and there was no bleeding; "100" indicated that the operation had to be stopped because of bleeding and the tourniquet re-applied. The quantity endpoints were "0" indicating too little blood and "100" indicating too much bleeding to continue the operation, such that a re-exanguination was needed.

The surgeon evaluated the amount of oozing of blood into the operation field and how this influenced the operation every 5 min. The oozing was quantified as minor, moderate or severe. "Minor" indicated an increase in the amount of blood so that the operation field could barely be identified, "moderate" indicated it was easy to "mop-up" the blood and "severe" indicated it was difficult to "mop-up" the field and the procedure had to be stopped.

The reduced visualisation was quantified as none, minor, moderate, more or severe with none = no bleeding at all; mild = a gauze swab had to be used but this did not delay the surgery; moderate = a gauze swab had to be used and this delayed the surgery; more = the operation had to be temporarily stopped to "mop-up" the blood; severe = the procedure had to be stopped.

In order to reduce bias, the hand surgeon had trained himself to evaluate the outcome measures for 6 months before the start of the study. Moreover, to reduce differences in these assessments during the study, it was conducted in a relatively short period of time.

The three different groups of demographic data were compared with Friedmann ANOVA test. The Mann–Whitney *U*-test was used to compare the results obtained for the different exsanguination procedures concerning quantity, quality, ooze and visualisation. All tests were two-sided. The results were considered significant at $p<0.05$. Results are given as means and standard deviation (SD).

The presumed statistics were based upon a predicted VAS score regarding the quality of the exsanguination of 5 (H0) and a change to 6.5 (H1). With a predicted standard deviation (SD) at 2, a risk of Type 1 error at 5% and a risk of Type 2 error at 10%, the study was calculated to require 150 patients. As the predicted standard deviation of the quality of exsanguination was relatively uncertain, we planned to do an interim analysis after having included 100 patients. This was the primary data analysis. After evaluating the result of the interim analysis, we decided not to include more patients since a significant result regarding the primary endpoint was observed.

RESULTS

We found no significant differences between the three groups with respect to the measured variables: age 50(16), height 174(9) cm, blood pressure systolic 146(22) mmHg and diastolic 86(16) mmHg, tourniquet pressure 250(24) mmHg, minutes from inflation of the tourniquet to the start of the operation 2.5(4.5) min and duration of the operation 45(18) min.

The results for the different exsanguination methods with respect to quality, quantity, ooze and visualisation are reported in Tables 1–5. In three cases, the oozing continued until the operation was finished and, in 19 cases, it stopped at a median of 35 min.

Table 2—Results of different exsanguination methods with respect to the quality and quantity of exsanguination (SD)

	Quality	*Quantity*
Elevation	9.1 (12.6)	8.8 (11.8)
Squeeze method	0.8 (1.6)	1.3 (2.5)
Esmarch bandaging	2.0 (3.4)	1.8 (2.4)

Table 3—Comparison of the different exsanguination methods with respect to the quality and quantity of exsanguination, the amount of oozing and how the visualisation of the operating field was affected

	Quality	*Quantity*	*Oozing*	*Visualisation*
Elevation versus squeeze	$P = 0.004$	$P<0.001$	$P = 0.005$	$P<0.001$
Elevation versus esmarch	$P = 0.009$	$P = 0.005$	$P<0.001$	$P<0.001$
Squeeze versus esmarch	No significance ($P = 0.45$)	No significance ($P = 0.07$)	No significance ($P = 0.09$)	No significance ($P = 0.98$)

Table 1—Demographic data (SD)

	Operating time (min)	*BP systolic*	*BP diastolic*	*Cuff pressure (mmHg)*	*Height (cm)*	*Weight*	*Age*	*SD*
Elevation	66 (26)	143 (22)	81 (17)	244 (23)	174 (9)	74 (15)	51	17
Squeeze method	65 (25)	145 (22)	87 (16)	249 (23)	172 (9)	74 (16)	49	16
Esmarch bandaging	60 (25)	150 (22)	90 (16)	259 (24)	175 (10)	78 (16)	51	16

Table 4—Cases in which oozing occurred

	None	*Moderate*	*Severe*	*Mean*
Elevation	18	16	0	1.14
Squeeze	28	5	0	1.02
Esmarch	33	1	0	1.01

Table 5—Distribution of cases according to reduced visualisation

	None	*Mild*	*Moderate*	*More*	*Severe*	*Mean*
Elevation	21	10	2	1	0	1.22
Squeeze	32	0	1	0	0	1.01
Esmarch	32	1	0	0	0	1.00

DISCUSSION

This study identifies, that in hand surgery, the use of both the ''squeeze method'' and Esmarch bandaging for exsanguination of the limb before inflation of the tourniquet is significantly better than simple elevation with respect to exsanguination and oozing. However, we were unable to detect any significant difference between the ''squeeze method'' and the more laborious process of applying an Esmarch bandage, but a larger study may have identified a significant difference between the two.

The results are in accordance with previous experimental studies (Alshawi and Scott, 2004; Blond and Madsen, 2002), and also with the clinical study of Colville and Small (1986). However, contrary to Colville and Small who found that about 3% of the patients had too little blood in the operative field, we did not observe this problem.

We had expected that some blood would pass beneath the tourniquet, into the surgical field and hinder visualisation after about 30 min. However, the small amount of oozing, which occurred in 22% of cases, stopped after about 35 min in all but three cases. This oozing was significantly more frequent in the elevation group (Group 1). We think this oozing is not the result of blood passing under the tourniquet, but is due to blood that remained in the arm after incomplete exsanguinations. Whichever explanation is correct, this oozing is not usually of significance. Colville and Small (1986) found that oozing as well as too little blood in the vessels were problematic, and this may depend on the type of surgery. A little blood in the vessels makes the raising of flaps quicker and allows more easy identification and cautery of the small vessels.

A criticism of this study is the difficulty measuring both the quality and quantity of the exsanguinations as well as the oozing objectively. We could not devise a precise method for quantifying any of these measurements and, therefore, relied on the opinion of a very experienced hand surgeon, who has trained himself for this study for a duration of 6 months.

Another criticism could be the short elevation time of 5 s. However, we have previously shown that this relative short time is sufficient for both young and old patients, and better than 1 or 2 min of elevation as a reactive hyperaemia does not occur (Blond and Madsen, 2002, 2003a, b).

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Received: 13 March 2007
Accepted after revision: 29 January 2008
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doi:10.1177/1753193408090123 available online at http://jhs.sagepub.com