A SAFE AND EFFECTIVE LOW PRESSURE TOURNIQUET

A PROSPECTIVE EVALUATION

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An unusually wide pneumatic tourniquet has recently become available; we provide a simple formula for its use with a low but effective inflation pressure. A prospective, randomised and controlled trial in 600 lower limb and 150 upper limb operations is reported.

The wide tourniquet (12.5 cm) was as effective at low pressure as was a conventional tourniquet (9 cm) inflated to significantly higher pressures. Fewer patients suffered from painful paraesthesiae after operation using the broad, low-pressure tourniquet.

Over eighty years have elapsed since Cushing (1904) introduced the pneumatic tourniquet but there are still no satisfactory answers to the questions of how long this unphysiological instrument may be left inflated (Bruner 1970; Dahlbäck 1970; Flatt 1972; Klenerman et al. 1980; Newman 1984) and what is a "safe" pressure (Fletcher and Healy 1983).

Clearly if complications after operation in a bloodless field are to be minimised (Ochoa, Fowler and Gilliatt 1972; Patterson and Klenerman 1979; Fahmy and Patel 1981), the surgeon should ensure that the period of ischaemia is as short as possible and the inflation pressure as low as possible. The minimal pressure to occlude arterial flow reliably in all cases is difficult to predict since a tourniquet does not necessarily apply a uniform pressure to all points within a limb (Sinclair 1948) and there is no simple relationship between the inflation pressure on the surface of the limb and the pressure induced within the deep vessels (Griffiths and Heywood 1973).

For practical purposes a formula for the inflation pressure of a pneumatic tourniquet should be uncomplicated and be related to the patient's systolic pressure (Fletcher and Healy 1983), the width of the tourniquet (Klenerman and Hulands 1979; Muirhead and Newman 1986) and the girth of the limb (Klenerman and Hulands 1979; Shaw and Murray 1982; Van Roekel and Thurston 1985; Muirhead and Newman 1986). Most

previously suggested mathematical formulae have been restricted to patients said to be "normotensive" and "not excessively obese"; they have not been evaluated in a prospective, controlled manner.

An unusually wide tourniquet (12.5 cm) has recently become available for clinical use (Stille-Werner UK, Woking, Surrey) and we have demonstrated that it reliably interrupted arterial flow at an inflation pressure significantly lower than that needed in a narrower cuff (Muirhead and Newman 1986).

A formula was developed for use with this cuff which was simple and could be used for all patients irrespective of obesity or hypertension. This was to inflate the tourniquet to a specified amount above the systolic blood pressure as measured when the patient was admitted to hospital; the specific increment was 125 mmHg for the leg and 35 mmHg for the arm. The latter figure was chosen because the intra-operative systolic pressure in the arm was shown not to rise by more than 20 mmHg above the pressure measured in the arm on admission: the small additional pressure ensured effective ischaemia.

This paper describes a prospective, randomised and controlled clinical trial of the wide tourniquet using these pressures.

METHODS

All patients having an orthopaedic operation on a limb under general anaesthesia in the Western Infirmary or the Gartnavel General Hospital, Glasgow were eligible for the study, excluding those in whom any local anaesthesia was used before or after surgery. The systolic pressure in the arm was recorded on admission. Before anaesthesia was induced a random selection for either a high or a low pressure tourniquet was made by an operating department assistant who opened an

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Table I. Detail of 745 operations under tourniquet control and of the patients involved

Operations	Arm tourniquet		Leg tourniquet	
	Low pressure	High pressure	Low pressure	High pressure
Number	76	74	296	299
Elective (<i>per cent</i>)	62	69.4	84.6	83
Acute (<i>per cent</i>)	38	30.6	15.4	17
Female patients (<i>per cent</i>)	46.5	45.5	55.9	52.3
Patient's age in years (mean $\pm$ s.d.)	41.0 $\pm$ 18.9	45.5 $\pm$ 17.4	43.3 $\pm$ 19.2	43.0 $\pm$ 17.9
Left side (<i>per cent</i>)	65	57.1	52.3	53.6
Tourniquet time in minutes (mean $\pm$ s.d.)	53.4 $\pm$ 36.2	59.2 $\pm$ 49.0	60.2 $\pm$ 42.1	61.2 $\pm$ 48.6
Methods of exsanguination (<i>per cent</i>)				
Esmarch bandage	47.7	27.9	87	87
Martin's bandage	38.6	51.2		
Pneumatic	11.4	16.3	7	10
Elevation only	2.2	4.7	6	3

unmarked, sealed envelope. When bilateral tourniquets were to be used the randomisation procedure was followed separately for each limb.

Each limb was exsanguinated according to the preference of the surgeon and the chosen cuff applied and inflated. The limbs in the low pressure group had a tourniquet 12.5 cm wide applied and inflated to above the systolic pressure recorded in the arm on admission; the amount above this pressure was 35 mmHg for operations on the arm and 125 mmHg for those on the leg. To the limbs in the control group the tourniquet previously in routine use was applied; this was 9 cm wide and was inflated to 250 mmHg or 400 mmHg for the arm and the leg respectively.

After the operation the surgeon completed a questionnaire in which he rated the performance of the tourniquet as satisfactory, less than satisfactory or unsatisfactory at the beginning, middle and end of the procedure.

All patients were examined on the day after their operation for signs of any complications such as skin damage, nerve palsies or vascular occlusion which could be associated with the use of a tourniquet. Formal sensory testing was not performed, but patients were asked about persisting paraesthesiae (defined as altered or painful sensations experienced at rest) in the operated limb distal to the tourniquet.

RESULTS

During the period of the trial 750 tourniquets were applied and satisfactory questionnaires were available for 745 cases (99.3%). There was no significant difference in tourniquet performance between the groups of patients undergoing acute or elective operations, therefore the results for both types of operation were combined. There were no significant differences in age, sex or side of operation between the groups of patients

having high and low pressure tourniquets on arm or leg (Table I).

Both types of tourniquets were reported to perform equally well at all stages of the operations (Tables II and III), though inflation pressures in the wide tourniquet were significantly lower than in the control group ($p < 0.05$).

No major complications due to the tourniquets were recorded during the trial but the frequency of painful paraesthesiae, usually of glove or stocking distribution, was significantly less ($p < 0.05$) in the legs of the patients on whom a low pressure tourniquet had been used (Table III). The same trend was noted ($0.1 > p > 0.05$) when the low pressure tourniquet was used on the arm (Table II).

DISCUSSION

It is difficult to quantify the effectiveness of a tourniquet. Ideally this should be done by weighing surgical swabs from a nominated group of surgeons performing a limited number of standardised operations in a finite time. In our survey surgeons of all levels of seniority and experience had no restrictions regarding operation, technique or timing. The adequacy of the bloodless field was judged personally by each surgeon, and his subjective assessment was recorded. The terms "satisfactory", "less than satisfactory" and "unsatisfactory" have been used in previous studies (Reid, Camp and Jacob 1983).

It appears to be generally accepted that a "safe" pressure for an upper limb tourniquet is 250 to 300 mmHg and for the lower limb 500 to 550 mmHg irrespective of the patient's blood pressure (Stewart 1975, pp 181-9; Edmonson 1980) but the reasons for these values are rarely given. Brigden (1980, pp 511-3) suggested that pressures of 275 mmHg and 550 mmHg were necessary in the arm and leg respectively to compensate for the padding of muscle and fat. Spiegel and Lewin (1945) recommended 450 mmHg for the arm

Table II. Detail of the performance of 150 tourniquets applied to the upper limb

	Low pressure (76)			High pressure (74)		
	Stage of operation			Stage of operation		
	Start	Middle	End	Start	Middle	End
<i>Surgeon's opinion</i>						
Satisfactory	74 97.4	71 93.4	70 92.0	70 94.6	69 93.2	69 93.2
Less than satisfactory	1 1.3	4 5.2	3 3.9	2 2.7	3 4.1	2 2.7
Unsatisfactory	1 1.3	1 1.3	3 3.9	2 2.7	2 2.7	3 4.1
Completely satisfactory at all stages		70 92.0			69 93.2	
<i>Tourniquet</i>						
Pressure in mmHg (mean $\pm$ s.d.)		166.9 $\pm$ 19.6			250	
Tourniquet time over two hours		12			9	
Number with paraesthesia 24 hours postoperatively		1			3	

Numbers in italics are percentages

and 750 mmHg for the leg whilst McElvenny (1945) employed pressures of 350 mmHg for the arm and 1150 mmHg for the thigh.

It seems rational to relate the tourniquet pressure to the patient's blood pressure. Sanders (1973) suggested 70 mmHg above the pre-operative systolic pressure and a similar value was agreed by Adams (1976, pp 4-6). Rorabeck (1980) recommended 100 to 150 mmHg above the systolic pressure and Klenerman and Hulands (1979) recommended twice the systolic pressure for a thigh tourniquet.

Most of these papers report neither the width of the tourniquet nor the time at which the baseline systolic blood pressure was recorded. The latter figure will vary widely according to whether it is recorded in the general practitioner's surgery, the outpatient clinic, the admission ward, the anaesthetic room or in the theatre at the start of the operation (O'Brien, Fitzgerald and O'Malley 1985). In the present study a broad (12.5 cm) tourniquet,

inflated to a relatively low pressure related to that recorded when the patient was admitted, was found to provide the same level of satisfaction as a narrower tourniquet inflated to an arbitrary but significantly higher pressure. The low pressure cuff resulted in a significantly reduced incidence of painful paraesthesiae on the day after operation.

Narrow tourniquets have occasionally to be used to allow access to certain anatomical sites. It is, however, suggested that the surgeon should choose the broadest possible tourniquet compatible with the proposed exposure. This will allow the use of lower inflation pressures which will lead to a gratifying reduction in the incidence of complications associated with the use of a tourniquet.

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Table III. Details of the performance of 595 tourniquets applied to the lower limb

	Low pressure (296)			High pressure (299)		
	Stage of operation			Stage of operation		
	Start	Middle	End	Start	Middle	End
<i>Surgeon's opinion</i>						
Satisfactory	296 100	295 99.7	292 98.6	295 98.7	294 98.3	295 98.7
Less than satisfactory	0 0	1 0.3	4 1.4	2 0.7	4 1.3	4 1.3
Unsatisfactory	0 0	0 0	0 0	2 0.7	1 0.3	0 0
Completely satisfactory at all stages		290 98.0			291 98.6	
<i>Tourniquet</i>						
Pressure in mmHg (mean $\pm$ s.d.)		252.2 $\pm$ 22.8			400	
Tourniquet time over two hours		10			15	
Number with paraesthesia 24 hours post operatively		1			4	

Numbers in italics are percentages

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