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Intra-operative pneumatic tourniquet — perceptions of use and complications in the orthopaedic community of South Africa

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Objectives. To assess views on use, maintenance and side-effects of the pneumatic tourniquet in the South African orthopaedic community.

Methods. A census-type questionnaire study was conducted of all 475 orthopaedic surgeons registered with the Orthopaedic Association of South Africa during 1993/94. The chi-square test was used to determine statistical significance between different groups of respondents.

Results. Seventy-seven per cent of the questionnaires were returned. Ninety-nine per cent of respondents used a pneumatic tourniquet. Eighty-four per cent believed that the tourniquet may damage underlying tissue both as a result of applied pressure effects and ischaemic consequences. Fifty-four per cent of respondents personally checked the calibration of the pneumatic tourniquet, although 76% of respondents believe that the apparatus needs to be checked at least once per month. More respondents who did not check the tourniquet apparatus than respondents who did check it believe that applied pressure does not cause tissue damage ($P < 0.001$), that the operating room technician or hospital engineer should be responsible for checking equipment ($P < 0.001$), and that equipment did not need to be checked more than once every 6 months ($P < 0.001$).

Conclusions. Although most orthopaedic surgeons are aware of the pneumatic tourniquet's side-effects, a minority appear to be unaware of the hazards of excessive applied pressure alone or excessive applied pressure caused by use of faulty equipment. It needs to be emphasised to these surgeons that regular checking of the pneumatic tourniquet apparatus is necessary in order to prevent postoperative complications ascribed to use of the tourniquet.

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Throughout history, surgeons have searched for the ideal apparatus to provide a bloodless operating field. Roman surgeons during the era of Julius Caesar used a 'constricting device' for amputations. In 1718, the French surgeon, Petit, developed a screw device for haemostasis, which subsequently became known as a 'tourniquet'.[1] In 1873, von Esmarch developed the rubber bandage tourniquet which still bears his name. In 1904, Cushing, apparently concerned with the number of side-effects caused by the von Esmarch rubber bandage, developed the pneumatic tourniquet, which was the forerunner of modern pneumatic tourniquet devices.[2]

Through the decades after the invention of the modern pneumatic tourniquet, clinicians have questioned their safety.[3-6] Deleterious effects on the underlying limb, particularly neural tissue, have been described[7-10] at cuff pressures between 300 and 500 mmHg. Similarly, ischaemic damage to underlying musculature and other tissues occurs after tourniquet application of 1 - 3 hours' duration.[11-16]

Methods to alleviate or reduce these side-effects have been described. For example, deflating the cuff for a period intra-operatively[17] or hypothermic limb-cooling techniques reduce the side-effects.[18] Formulas have also been derived using the patient's systolic blood pressure or limb girth circumference to minimise the pressure needed to cause haemostasis and thus prevent tissue damage.[19,20]

In addition, faulty tourniquet apparatus, which under-reads the applied pressure, may also cause harm to the underlying tissue.[16,21,22] A study of 13 pneumatic tourniquet devices at six different hospitals in the Western Cape by Irving *et al.*[18] found that 62% were more than 5% inaccurate,[16] with one cuff under-reading by 350 mmHg.

Therefore, in summary, the pneumatic tourniquet device is used frequently during surgical procedures, despite controversy about potential side-effects and poorly calibrated instruments. The perceptions of orthopaedic surgeons in South Africa on the use of these devices are not known. The aim of this study was therefore to sample the opinions of the entire orthopaedic surgeon population in South Africa in this regard.

Subjects and methods

A census-type questionnaire study was undertaken of the entire orthopaedic community of South Africa ($N = 475$) to determine their perception of use of a pneumatic tourniquet during surgery. After the questionnaire had been compiled, a pilot study was performed on a small sample of hospital-based orthopaedic surgeons ($N = 8$), and any problematic questions were adjusted.

All orthopaedic surgeons listed by the South African Orthopaedic Association as surgically active were included in the study. A second questionnaire was sent to those surgeons who did not return the first mailing, and a third questionnaire to those who did not respond to either the first or the second mailing. A short questionnaire was sent to

those who did not respond to any of the three questionnaires, asking the reasons for their lack of response.

The questionnaire sought the following information: (*i*) type of practice in which orthopaedic surgeons worked and area of orthopaedics in which they perceived themselves to be sub-specialised; (*ii*) tourniquet techniques used during their surgery; (*iii*) opinions on pneumatic tourniquet-induced damage; (*iv*) opinions on pneumatic tourniquet maintenance.

A chi-square test was used to determine differences between groups of respondents. Statistical difference was accepted when $P < 0.05$.

Results

Of the 475 questionnaires sent out, 368 were returned, giving an overall return rate of 77%. Of the 368 returns, 60 were discarded (16%) because of uninterpretable data. Forty-eight per cent of the respondents returned the first mailing, 10% the second and 12% the third. Fourteen per cent returned the non-return questionnaire. The main reasons for not filling in the original questionnaire (multiple responses were allowed) were that it was not relevant to the respondent's field of interest (44%), they were retired (17%), had not received any of the other three questionnaires (15%), personal reasons (8%), incorrect grammar (2%), incorrect language (2%) and other reasons (19%).

Table I details the descriptive characteristics of the respondents, nearly all of whom had used a pneumatic tourniquet during surgery within the last 10 years (99%). Most (95%) had used a tourniquet on both the upper and lower limbs. Of the respondents who had used tourniquets, 68% elevated the limb, 59% used an Esmarch rubber bandage, 23% used hand pressure and 6% used crepe bandages as adjunctive procedures to the pneumatic tourniquet to exsanguinate the limb prior to surgery. A significantly higher number of doctors in private practice ($P < 0.001$) use the Esmarch rubber bandage compared with their colleagues in hospital practice.

Table I. Descriptive characteristics of the 308 orthopaedic surgeon respondents (%)

Region of respondents	
Gauteng (Southern Transvaal)	31
Northern Transvaal	21
Western Cape	20
KwaZulu-Natal	14
Eastern Cape	7
Free State	7
Type of practice	
Private practice only	40
Hospital practice only	20
Private and hospital practice	40
Subspecialty	
General	41
Knee	14
Spine	8
Hip	8
Shoulder	8
Hand	5
Other	16

The majority of all respondents (86%) felt that the pneumatic tourniquet could cause damage to the underlying limb during surgery. They believed the damage to be caused by both direct applied pressure and ischaemic consequences (84%), by applied pressure alone (9%) or by ischaemic consequences alone (7%).

Table II shows the maximum tourniquet pressures that the respondents perceived to be safe. The majority of respondents (64%) believed that a tourniquet pressure of 400 mmHg or less was safe for the lower limb. The same percentage believed that a systolic pressure of 300 mmHg or less would prevent damage to the upper limb. To calculate the safe maximum pressure for the lower limb, 22% of respondents used a formula based on systolic blood pressure, and 24% a similar formula for the upper limb. Of the respondents who perceived applied pressure to be problematic, a significant difference ($P < 0.001$) existed between the pressure level perceived to be safe for the upper and for the lower limb.

Table II. The maximum systolic pressure (mmHg) of the pneumatic tourniquet which 308 orthopaedic surgeons perceive as being safe for preventing tissue damage (%)

	Lower limb	Upper limb
< 100 mmHg	0	1
< 200 mmHg	2	21
< 300 mmHg	38	42
< 400 mmHg	24	1
< 500 mmHg	4	0
> 500 mmHg	0	0
Formula*	22	24
Not applicable	10	11
Total	100	100

* Formula based on systolic blood pressure of the patient being operated on.

Table III shows the time period that respondents perceived to be safe for preventing tissue ischaemia. The majority of respondents (84% for the lower limb and 88% for the upper limb) thought that a tourniquet time of 2 hours or less would prevent underlying tissue damage.

Table III. The maximum time limit for tourniquet use which 308 orthopaedic surgeons perceive as being safe for preventing tissue damage (%)

	Lower limb	Upper limb
30 minutes	0	3
1 hour	12	25
2 hours	72	60
3 hours	5	1
4 hours	0	0
5 hours	0	0
> 5 hours	0	0
Not applicable	11	11
Total	100	100

Table IV shows that the majority (81%) of respondents deflate the cuff intra-operatively. While most (52%) deflated the cuff 1 - 2 hours into the operation, some (20%) waited

until the 3rd hour of the operation before they first deflated the cuff. Only 8% of respondents deflated the cuff within the 1st hour of the operation. Another group of respondents (19%) did not deflate the cuff at all during an operation.

Table IV. The intra-operative use of pneumatic tourniquets by 308 orthopaedic surgeons (%)

Is cuff ever deflated intra-operatively?	
Yes	81
No	19
Total	100
How long into the operation is cuff first deflated?	
30 minutes or less	2
31 - 60 minutes	6
61 - 120 minutes	52
121 - 180 minutes	20
Other	1
Cuff not deflated	19
Total	100
How long is the period of deflation?	
0 - 5 minutes	21
6 - 10 minutes	36
11 - 15 minutes	14
15 - 20 minutes	7
> 20 minutes	3
Cuff not deflated	19
Total	100

Although 54% of all respondents personally check the calibration of the pneumatic tourniquet before surgery, 40% of all respondents feel that the theatre technician, the equipment suppliers (21%), the hospital technician (21%) or the anaesthetist (5%) should be responsible for checking the equipment.

Of all the respondents, the highest proportion believe that the tourniquet apparatus should be checked monthly (41%), followed by weekly (35%), every 6 months (21%) and yearly (2%). One respondent believed that the equipment did not need to be checked at all. More respondents in the group that checked the tourniquet apparatus believed that applied pressure is the cause of tissue damage, compared with those respondents in the group who did not check the calibration ($P < 0.001$). In addition, more respondents in the group that did not check the tourniquet equipment believed that the operating room technician or hospital engineer should check the equipment, compared with those who did check the tourniquet apparatus ($P < 0.001$). Similarly, more respondents who did not check the tourniquet apparatus did not believe the apparatus needed to be checked more than once every 6 months or longer compared with those who did check the tourniquet apparatus ($P < 0.001$).

Discussion

The first finding of this study is that almost all orthopaedic surgeons in South Africa used the pneumatic tourniquet on both the upper and the lower limbs. In addition, most believed that the pneumatic tourniquet could cause damage to the underlying limb, either by applied pressure or ischaemic damage, which is in accordance with the evidence reported earlier.[7-16] The respondents who believed that applied pressure did not cause damage to the underlying tissue also checked the functioning of the pneumatic tourniquet less frequently. This is cause for concern, because studies have shown that malfunctioning gauges can under-read the true pressure significantly, and that there are a number of faulty tourniquet apparatuses in certain hospitals.[16,20,21]

The next finding was that 24% of surgeons still feel that a tourniquet pressure of 400 mmHg and 4% that 500 mmHg is a safe maximum value, despite studies showing the dangers of these high values.[7-10] There was a significant difference between the safe tourniquet pressure allowed for the upper and lower limbs, with lower pressures being perceived as safer for the upper than the lower limb. This difference was probably caused by the fact that the upper and lower limb have different circumferences with the larger lower limb being perceived as less susceptible to damage.

The large majority of respondents believed that a tourniquet time of longer than 2 hours was deleterious to the underlying tissues. This is in accordance with the findings published in the literature.[11-16] Although the majority of respondents deflate the cuff at some period intra-operatively, which reduces the possibility of ischaemic complications, a minority of surgeons use a formula based on systolic pressure or other methods in an attempt to decrease morbidity due to applied pressure effects. At present it therefore appears that, while acknowledging the hazards of ischaemia in the use of the pneumatic tourniquet, certain surgeons do not realise the role of applied pressure and faulty apparatus in causing tissue damage, as reported in the literature.[7-10,16,20,21]

Finally, it was found that only half of the respondents checked the tourniquet personally. The remainder believed that the other members of the surgical team should be responsible for checking the efficacy of the tourniquet apparatus. More attention should be focused on the checking and calibration of tourniquets, particularly as a study performed previously by Irving[18] has highlighted the extent of defective tourniquet apparatus in Western Cape hospitals.

The high rate of response to the questionnaire ensures that the conclusions derived from the study are representative of the population from which it was drawn. But the use of a tourniquet is not limited to orthopaedic surgeons. These findings may therefore be important for all branches of surgery that use the pneumatic tourniquet.

In conclusion, the majority of orthopaedic surgeons in the South African orthopaedic community use the tourniquet intra-operatively. Although most orthopaedic surgeons are aware of the pneumatic tourniquet's side-effects, a minority appear to be unaware of the hazards of excessive applied pressure alone and excessive applied pressure caused by use of faulty equipment. It needs to be emphasised to these surgeons that regular checking of the pneumatic tourniquet apparatus is necessary in order to prevent postoperative complications ascribed to use of the tourniquet, as described in the literature.

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