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Pain and paraesthesia produced by silicone ring and pneumatic tourniquets

A. Mohan, A. Baskaradas, M. Solan and P. Magnussen
Department of Orthopaedic Surgery, The Royal Surrey County Hospital NHS Trust, Egerton Road, Guildford, UK

Abstract
Twenty volunteers were recruited to compare a novel, silicone ring tourniquet (the Hemaclear® tourniquet) with a pneumatic tourniquet. After application of the tourniquets, the pain and paraesthesia experienced by the participants was scored at 1 minute, 5 minutes, and 10 minutes. This was repeated with the tourniquets on the forearm. On the upper arm, the silicone ring tourniquet was associated with a significantly lower pain score than the pneumatic tourniquet. The incidence of paraesthesia was also lower with the silicone ring tourniquet. When applied to the forearm, there was no statistically significant difference in pain scores between the two types of tourniquets. However the incidence of paraesthesia was again lower with the silicone ring tourniquet.

Keywords
Tourniquet, pain tolerance, paraesthesia

Introduction

Upper limb surgery is often done under local anaesthesia and the use of a tourniquet. Esmarch described the first use of his tourniquet in 1873 as a means of providing a bloodless field and the pneumatic tourniquet was introduced to limb surgery in 1904 by Harvey Cushing (Klenerman, 1962). Since then there have been many developments in the field of tourniquets, some of which have been influenced by military use (Welling et al., 2006).

One tourniquet system which has shown good results in upper limb surgery done under local anaesthesia is the Hemaclear® system (also known as S-MART™ and first developed in 1999 by OHK Medical Devices, Haifa, Israel) (Boiko and Roffman, 2004). The Hemaclear® system consists of a silicone ring (internal diameter 52 mm, external diameter 76 mm) wrapped within an elastic sleeve or 'stockinette' and with two straps attached to pull handles (Figures 1 and 2). It is applied by placing it on the patient's fingers and rolling it up the limb to the desired occlusion site by pulling on the straps (Figures 2 and 3).

The risks and benefits of using a tourniquet have been much discussed (Odinsson and Finsen, 2006). The new silicone ring tourniquet has shown good efficacy and safety (Boiko and Roffman, 2004; Eidelman et al., 2006; Norman et al., 2009). However, the pain tolerance in patients undergoing hand surgery with the use of this new tourniquet system has not been reported. We conducted a comparative study to assess the pain tolerance scores and paraesthesia experienced by patients when using the silicone ring tourniquet compared with a pneumatic tourniquet. We also compared upper arm and forearm tourniquets.

Methods

Twenty healthy volunteers comprising ten men and ten women aged between 23 and 55 years were recruited. The study was split into two parts to look at the upper arm and forearm separately. All 20 volunteers were included in both parts of the study. All the volunteers were from a non-medical background and were asked questions about any discomfort associated with the tourniquets, which were applied at the same time. The volunteers were blinded to the outcome.

In the first part, the pneumatic tourniquet was applied to one arm of the participant and the silicone ring tourniquet was applied to the other arm simultaneously. In the second part of the study, the pneumatic tourniquet was applied to one forearm of the participant and the silicone ring tourniquet was applied to the other forearm. Thus, each

Corresponding author:
Mr Arvind Mohan, Royal Surrey County Hospital NHS Foundation Trust, Department of Trauma and Orthopaedics, Egerton Road, Guildford, Surrey, GU2 7XX, UK
Email: arvindmohan@doctors.org.uk

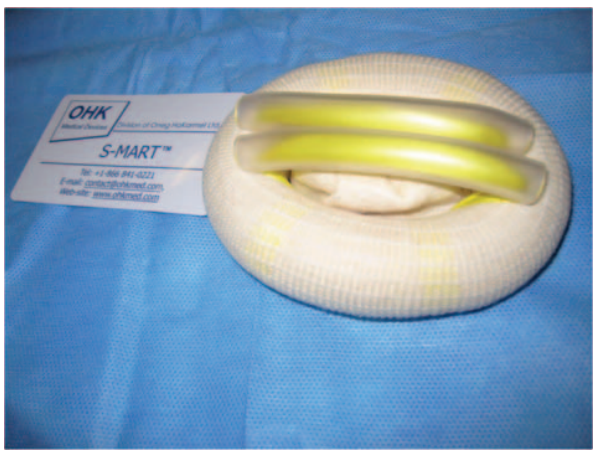

Figure 1. The 'Hemaclear®' or silicone ring tourniquet.

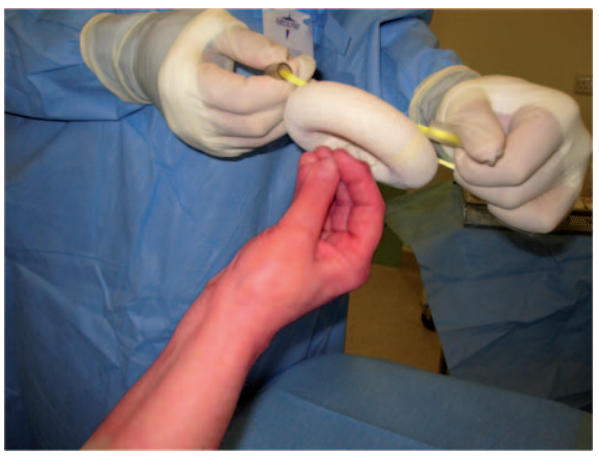

Figure 2. Holding the straps to position the tourniquet.

volunteer acted as his/her own control. The upper arm tourniquet was applied 10 cm above the medial epicondyle and the forearm tourniquet 10 cm below this point.

The pneumatic tourniquet (Oak Medical Services Ltd, North Lincolnshire, DN20 8PD) was placed over four layers of orthopaedic wool after exsanguination with a Rhys-Davies exsanguinator, and a size 45/9 pneumatic cuff was inflated to a pressure 100 mmHg above systolic blood pressure.

The silicone ring tourniquet was directly applied after skin preparation without the need for wool or exsanguination and the size was chosen according to the limb circumference and the systolic blood pressure of the patient.

After application of the tourniquet, pain experienced by the participants was scored out of 10 (with '0' being no pain and '10' being worst pain ever) at 1 minute, 5 minutes and 10 minutes in both

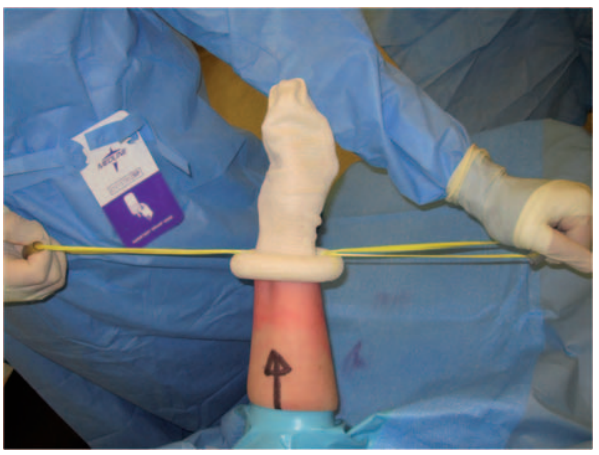

Figure 3. Rolling the silicone ring to the desired position.

parts of the study. Paraesthesia was scored '0' if there was no numbness or tingling at the site of or distal to the tourniquet, and '1' if either of these was experienced.

Each tourniquet was applied by the same investigator (A.M.). No actual surgical procedures were done and the tourniquets were removed after 10 minutes.

Once the data had been collected, two-tailed paired *t*-tests were used for statistical analysis. A *p*-value of <0.05 was considered statistically significant.

Results

The results are summarized in Table 1.

When the tourniquets were applied to the upper arm, the average pain score of the 20 participants after the first minute was similar for both the pneumatic and the silicone ring tourniquets. At 5 minutes, the average pain scores with the silicone ring tourniquet dropped below that experienced with the pneumatic tourniquet. Overall, it was found that in the upper arm, after 10 minutes, the silicone ring tourniquet was associated with a significantly lower pain score than with a pneumatic tourniquet.

When the tourniquets were applied to the upper arm, paraesthesia was more common with the pneumatic tourniquet than with the silicone ring tourniquet; six out of 20 participants experienced paraesthesia at 1 minute with the pneumatic tourniquet, compared with only one with the silicone ring tourniquet. By 10 minutes, 16 of the 20 participants wearing pneumatic tourniquets on the upper arm were experiencing paraesthesia. Of these, two were severe and three found the discomfort so unbearable that they had to have the tourniquet removed. In comparison, at 10 minutes, only four of the

Table 1. Pain scores and presence of paraesthesia, values are given as mean (SD)

	1 minute	5 minutes	10 minutes	*p*-value (10 mins)
Pain scores at upper arm				
Pneumatic tourniquet	4.0 (1.5)	4.3 (1.6)	5.7 (2.5)	<0.01
Silicone ring tourniquet	4.7 (1.6)	3.1 (1.6)	3.7 (2.3)	
Paraesthesia at upper arm				
Pneumatic tourniquet	0.3 (0.5)	1.2 (0.5)	3.2 (0.5)	<0.01
Silicone ring tourniquet	0.1 (0.22)	0.3 (0.2)	0.8 (0.4)	
Pain scores at forearm				
Pneumatic tourniquet	4.1 (1.6)	4.3 (1.7)	2.3 (1.7)	0.09
Silicone ring tourniquet	5.5 (1.1)	3.5 (1.5)	1.9 (1.2)	
Paraesthesia at forearm				
Pneumatic tourniquet	0.5 (0.5)	0.7 (0.5)	0.8 (0.4)	<0.01
Silicone ring tourniquet	0.1 (0.2)	0.2 (0.4)	0.2 (0.4)	

participants experienced paraesthesia with the silicone ring tourniquet. The paraesthesia was described as mild though one had to have the silicone ring tourniquet removed (this participant had to have the pneumatic tourniquet removed as well). Overall, it was found that in the upper arm, after 10 minutes, the silicone ring tourniquet was associated with a significantly lower incidence of paraesthesia than with a pneumatic tourniquet.

In the second part of the study with tourniquets applied to the forearm, pain scores with both types of tourniquet were lower than when placed on the upper arm. With the silicone ring tourniquet, the average pain score at 1 minute was again 5. However the pain scores decreased at both the 5 minute and 10 minute points. With the pneumatic tourniquet, pain scores were initially slightly lower. However, at 5 minutes, the pain scores increased then fell at 10 minutes. There was no statistically significant difference in pain scores between the two types of tourniquets when applied to the forearm.

With forearm tourniquets, only one participant wearing the silicone ring tourniquet experienced paraesthesia at 1 minute compared to eight of those wearing pneumatic tourniquets. At 10 minutes, only four of the participants wearing silicone ring tourniquets experienced paraesthesia compared to 15 participants wearing pneumatic tourniquets. There was significantly less paraesthesia at the forearm with the silicone ring tourniquet than with the pneumatic tourniquet.

Discussion

Our results have shown that the silicone ring tourniquet gives a lower pain score than the pneumatic tourniquet in the upper arm though pain scores appear to be fairly similar in the forearm. In terms of paraesthesia, the silicone ring tourniquet produces much less than the pneumatic tourniquet and as a result is better tolerated.

Any surgical procedure that is carried out under local or regional rather than general anaesthetic relies on maintaining the comfort of the patient to allow surgery to continue. We found that participants were able to tolerate the silicone ring tourniquet for longer, thereby providing a longer for surgical intervention. Furthermore, less discomfort experienced during surgery makes it more likely that patients will have a positive outcome (Kehlet and Wilmore, 2002). This, together with its speed and ease of draping suggest the silicone ring tourniquet may be a useful alternative to the pneumatic tourniquet.

On a biomechanical level, the difference between the two tourniquets is primarily due to the surface area occluded by each type. Animal studies using electron microscopy have shown that pneumatic tourniquets can cause compression of nerves that is sufficient to displace the nodes of Ranvier (Ochoa et al., 1972). The damage done by just 2 hours of tourniquet time can be detected for days and weeks afterwards. Unlike the pneumatic tourniquet, the silicone ring tourniquet does not use a wide cuff and the amount of nerve damage is thought to be much less. However, MRI or nerve conduction studies may be needed to assess this (Mittal et al., 2008).

We found that forearm tourniquets produced marginally more paraesthesia than upper arm tourniquets but due to the lower pain scores, no patients had to take them off. Maury and Roy (2002) in a study of 24 volunteers had similar findings and reported that a forearm tourniquet was tolerated for 7 minutes longer than an upper arm tourniquet.

Some participants had difficulty with all tourniquets and this may have affected the results.

However, if these participants had been excluded, this would have improved the scores obtained with the silicone ring tourniquet. In the clinical settings, such participants would be probably better suited to general rather than local anaesthesia.

Our results show that the most comfortable position to place a tourniquet is on the forearm. The most comfortable type of tourniquet to use is the silicone ring tourniquet. The improvement in comfort between the silicone ring tourniquet and pneumatic tourniquet is most evident when used on the upper arm. Patient comfort with any tourniquet system is largely related to the pain tolerance and paraesthesia associated with the tourniquet system.

Conflict of interests

None declared.

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