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The use of sterile tourniquet in Paediatric Orthopaedics

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Abstract

Background: This prospective study was designed to highlight the pros and cons of the application of sterile tourniquet in children with congenital deformities, benign tumors or fractures of upper and lower limbs.

Material and Methods: From October 2007 to April 2008 this device was used in 40 children (23 boys and 17 girls), with an average of 5.6 years old (range from 6 months to 14 years), who were treated surgically in our Department. Twenty three operations affected the upper, and 23 the lower limbs. The effectiveness of this type of tourniquet was evaluated according to specific criteria and was compared to that of pneumatic tourniquet, not only during the operation, but also post-operatively.

Results: There was no failure of application or cutaneous complications after its removal and no complaints from the young patients at all as well.

Conclusions: Sterile tourniquet seems to advantage due to its ease of application, shortening of operative exsanguination time, success in retaining a sterile field and easy replacement in operations lasting over ninety minutes. Moreover, no skin plicas or necrosis can be found after its removal and the surgeon needs no help by the nurse to put it in place. Issues of concern are its operatively stable pressure (inability to up-or-down regulate), the contraindications of use in operations lasting more than ninety minutes and its insufficiency in unstable fractures or dislocations.

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INTRODUCTION

A bloodless technique in limb operations is the safest procedure applied in Paediatric Orthopaedics because it simplifies the surgeon's work and reassures parents' fears. The goal of a bloodless operation is traditionally achieved by the use of Esmarch exsanguination bandage and application of pneumatic tourniquet. However, in Paediatric Orthopaedics, one finds special circumstances that hinder the uneventful use of the traditional Esmarch bandage and may give negative results. For instance, the length of humerus and femur are so small that may make the use of pneumatic tourniquet, for the removal of an osteoid osteoma in humerus or a plastic restoration of quadriceps in a child with arthrogryposis and genu recurvatum, problematic (Figure 1). Moreover, femur's conical shape in overweight children allows the progressive sliding of the pneumatic tourniquet distal to its initial position during the operation, leading to loss of exsanguination and sterility in the surgical field.

Additional problems that are known to be associated with the use of pneumatic tourniquets are skin abrasions and chemical burns[1,2]. Not seldom we find that the wear due to the intensive use produces leaks in the elastic tubes or central apparatus resulting in reduction of the initial pressure. There are also cases where the pneumatic tourniquet was accused for cross-contamination[3].

We hereby report our experience with the use of a sterile tourniquet (S-MART, OHK Medical Devices) in order to analyze all the advantages and disadvantages of the method.

MATERIAL AND METHODS

In this prospective study we used the sterile tourniquet

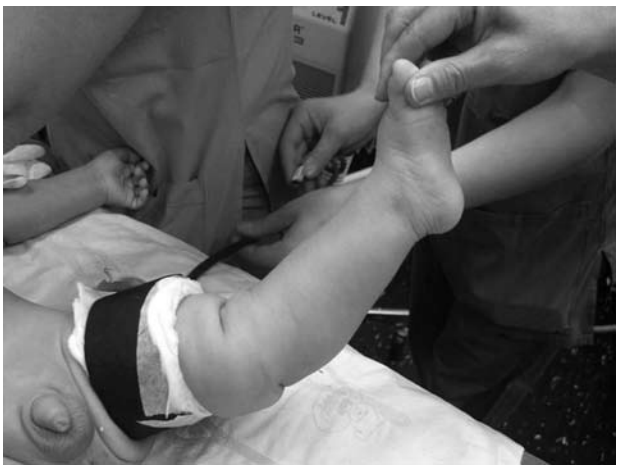

Figure 1. Femur's length is so small that makes the use of pneumatic tourniquet, for plastic restoration of quadriceps in a child with arthrogryposis and genu recurvatum, problematic.

in operations of upper and lower limbs in infants and children that were hospitalized in our Department from October 2007 to April 2008. Forty children (23 boys and 17 girls) suffering from congenital deformities, benign tumors or fractures in limbs were submitted into operation. Mean age of the patients was 5.6 years old (range from 6 months to 14 years). Twenty three operations in upper and 23 in lower limbs were conducted as we can see in Table 1. Exclusion criteria were unstable or particularly displaced fractures, dislocations, severe skin disorders and procedures with estimated surgical time more than 2 hours. Limb dimensions smaller than 24 centimeters in the site where the tourniquet was to be placed, did not discourage us despite the relevant references[1].

In order to completely evaluate our results from this method we used specific criteria in conjunction with its applicability and safety. These criteria were the following:

1. Ease of application
2. Time for application
3. Tourniquet position on the limb
4. Quality of exsanguination-bleeding upon first incision
5. Quality of exsanguination during the whole procedure
6. Interference with surgical field
7. Joint mobility distal and proximal to the tourniquet
8. Ease of removal
9. Scrub nurse's opinion
10. Postoperative complications

In postoperative complications we included infection, deep venous thrombosis, neurological deficits, compartment syndromes and postoperative pain, abrasions, petechias or chemical burns at tourniquet site[3-5]. The evaluation of all these complications was completed the first ten postoperative days.

The type of the tourniquet used was SET (Surgical Exsanguination Tourniquet), S-MART, OHK Medical Devices with the Israel (Haifa) being the country of origin. This type consists of

1) an elastic ring,
2) a cylindrical stockinet wrapped round the ring and
3) two pull straps.

The tourniquet device is sterile in its pack and for single use only. It is placed on the patient's fingers or toes, depending on the occasion, by the orthopaedic surgeon, in a previously appropriately prepared surgical field (Figure 2a). Pulling the straps vertically to the longitudinal axis of the limb the elastic ring rolls up the limb quickly and without effort until its end point of application (Figure 2b). While rolling the elastic ring squeezes the blood from the vessels back into the central circulation and simultaneously prevents the arterial inflow.

At that point the limb is covered by the sterile elastic stockinet at all its length. By this way the SET replaces the Esmarch bandage, the pneumatic tourniquet and the sterile stockinet. We open (or remove) with scissors the part of the stockinet that covers the incision site and now the operation can continue under sterile and bloodless conditions (Figure 2c). After the end of the operation the elastic ring can be cut with the use of a scalpel size no.21 with the help of a special plastic card (Figure 2d).

Three sizes of the S-MART were available to us during the study; the small device (for limbs with a circumference of 15-50cm) colored in pink, the medium size (suitable for limbs that are 20-80cm in circumference) colored in yellow, and the large size (for limbs with a circumference of 40-100cm) colored in blue. For the selection of the appropriate size for each occasion, we estimated the distance from the tip of toes or fingers to the position where the ring was to be placed and the circumference of the limb at the application site. With the use of tables we were choosing the size and knew the pressure applied.

RESULTS

The SET was applied successfully in all our cases despite our initial reservations. According to the criteria used concerning the applicability and safety of the method, we can make some remarks shown on Table 2. The use and final application of the device were judged as easy, after we had dealt with the initial difficulties consulting carefully the manufacturer's manual. The SET was kept in place and did not move, neither in children with small length of humerus or femur, nor in overweight children with conical shaped limb as we would expect to happen if pneumatic tourniquet was used.

The time required for its application was not longer than 60 seconds, in any occasion. The average tourniquet time with the SET was 47 minutes, with a range of 10 to 80 minutes. It was placed at the upper arm level in 23 cases and at in the thigh level at 23 procedures. We did not choose in any case the median part of forearm for

Table 1.

No.	Tourniquet Size		Area of application	Procedure time	Sex	Diagnosis	Age (years)
1	Pink	15′	Humerus	Opening a tendon sheath	M	Trigger thumb	2.3
2	Yellow	30′	Humerus	Excision	F	Wrist ganglion	4.2
3	Yellow	60′	Humerus	Finger separating	M	Hand Syndactyly	2.1
4	Yellow	30′	Humerus	Excision	F	Wrist ganglion	7.8
5	Yellow	60′	Humerus	Finger separating	M	Hand Syndactyly	2.5
6	Pink	10′	Humerus	Opening a tendon sheath	A	Trigger thumb	1.8
7	Yellow	45′	Humerus	ORIF	F	Medial epicondyle fracture	8.5
8	Yellow	60′	Humerus	ORIF	M	Olecranon fracture	10.2
9	Yellow	60′	Thigh	Broad syndesmolysis	M	Congenital Club foot	0.5
10	Pink	15′	Humerus	Opening a tendon sheath	F	Trigger thumb	2.2
11	Pink	12′	Humerus	Opening a tendon sheath	F	Trigger thumb	2.5
12	Yellow	60′	Thigh	Broad syndesmolysis	M	Congenital Club foot	0.7
13	Yellow	75′	Humerus	ORIF	F	Monteggia fracture	12.5
14	Pink	10′	Humerus	Opening a tendon sheath	F	Trigger thumb	3.2
15	Yellow	60′	Humerus	ORIF	F	Humeral condyle fracture	8.5
16	Yellow	70′	Humerus	ORIF	M	Forearm fracture	10
17	Blue	45′	Thigh	Excision of the exostosis	M	Tibial exostosis	11.9
18	Pink	15′	Humerus	Opening a tendon sheath	M	Trigger thumb	1.5
19	Yellow	60′	Thigh	Broad syndesmolysis	F	Congenital Club foot	0.6
20	Blue	80′	Thigh	Green-Grice arthrodesis	M	Flexible pes valgus	13.5
21	Yellow	60′	Humerus	ORIF	F	Radial head fracture	10.2
22	Pink	12′	Humerus	Opening a tendon sheath	M	Trigger thumb	2.8
23	Pink	20′	Humerus	Opening a tendon sheath	F	Trigger thumb	1.8
24	Yellow	60′	Thigh	Broad syndesmolysis	F	Congenital Club foot	0.7
25	Yellow	60′	Humerus	ORIF	F	Humeral condyle fracture	9.5
26	Yellow	75′	Humerus	ORIF	M	Monteggia fracture	13.8
27	Blue	45′	Thigh	Excision of the exostosis	F	Tibial exostosis	12.7

operations in the hand or the tibia, for operations in the foot. The exsanguination quality upon first skin incision was excellent, provided no need for hemostasis was apparent. But also during the whole operation the quality of exsanguination remained in the same excellent level provided the applied pressure was stable. The surgical field was not disturbed in any case from the presence of SET and the surgeon fulfilled his duty under absolute sterile and bloodless conditions. The mobility of the joints distal and proximal to the application site was kept free and the SET was removed without any problem. Scrub nurse's opinion was written down, something that is permanently omitted. She was complaining about the use of sterilized scissors to open the applied stockinet in the beginning of the operation (Figure 3) and was concerned about the presence of free particles of cut stockinet near the surgical field that are difficult removed (Figure 4).

As far the postoperative complications are concerned, we tried to find out which of them were attributed to the use of SET in the first 10 days following the operation. No signs of infection, deep vein thrombosis, neurological deficit, compartment syndrome or postoperative pain at application site were mentioned. In none of our patients did we find signs or symptoms of soft-tissue damage, petechias or chemical skin burns.

DISCUSSION

In this study, we report our experience using a new exsanguination tourniquet in infants and children suffering from congenital deformities, benign tumors or fractures of upper and lower limbs. Our impression is very favorable of the applicability and safety of this method in comparison with the use of traditional tourniquet method. It proved to be very useful in operations conducted only a few cm distally to the axilla or groin area, where the

Table 1. *(cont.)*

No.	Size	Tourniquet time	Area of application	Procedure	Sex	Diagnosis	Age (years)
28	Pink	10′	Humerus	Opening a tendon sheath	F	Trigger thumb	3.8
29	Yellow	30′	Thigh	Finger excision	F	Foot polydactyly	1.4
30	Yellow	60′	Thigh	Bone grafts	M	Fibular aneurysmal cyst	5.5
31	Blue	45′	Thigh	Excision of the exostosis	F	Tibial exostosis	11.5
32	Pink	15′	Humerus	Opening a tendon sheath	M	Trigger thumb	3.8
33	Yellow	30′	Thigh	Cyst excision	F	Popliteal cyst	4.5
34	Yellow	60′	Thigh	Broad syndesmolysis	M	Congenital Club foot	0.6
35	Yellow	30′	Thigh	Finger excision	F	Foot polydactyly	1.2
36	Yellow	70′	Thigh	Quadriceps plastic restoration	M	Arthrogryposis	1.2
37	Yellow	75′	Thigh	Open reduction	F	Congenital vertical talus	1.5
38	Blue	60′	Thigh	Excision of the nidus	M	Osteoma of femoral condyle	14
39	Blue	45′	Thigh	Excision of the exostosis	F	Tibial exostosis	3.4
40	Blue	80′	Thigh	Green-Grice arthrodesis	M	Flexible pes valgus	13.8
41	Yellow	70′	Thigh	Quadriceps plastic restoration	M	Arthrogryposis	1.6
42	Yellow	75′	Thigh	Open reduction	F	Congenital Vertical Talus	1.6
43	Yellow	60′	Thigh	Broad syndesmolysis	M	Congenital Club foot	0.6
44	Blue	45′	Thigh	Removal of Nancy nails	M	Fracture of femur	12.2
45	Yellow	60′	Humerus	ORIF	F	Radial head fracture	8.2
46	Yellow	60′	Thigh	Broad syndesmolysis	M	Congenital Club foot	0.7

space is insufficient for the use of pneumatic tourniquet. Additionally, it proved to be particularly useful when the children's limbs are small and conical shaped leading the pneumatic tourniquet to migrate distally to its initial position causing loss of cuff pressure, loss of resultant exsanguination and contamination of the surgical field.

The achieved exsanguination was satisfying in such a degree that no major hemostasis was needed, reducing the amount of blood loss. It also helped the surgeon recognize the relevant anatomy especially in hand operations[6]. Application time was minimal (less than 60 seconds) contributing to anesthesiologist's work and to a more straightforward progress of the operation.

The pressure applied by the elastic ring was stable during the whole procedure and depended on the distance between the tip of fingers or toes and the application point, and the circumference at that point. Using tables we were choosing the size and knew the exact pressure applied. For example, in finger-application site distance of 15 to 50cm and circumferences in application point between 14 and 28cm, the pressure varied between 180 and 210mm Hg-pink colored tourniquet. For distances between 20 and 80cm and circumferences between 24 to 40cm the pressure varied between 230 and 260mm Hg (yellow color). For distances ranging from 40 to 100cm and for circumferences from 24 to 56cm the pressure varied between 260 and 330mmHg (blue color).These pressures while blocking blood flow in the limb, they do not suppress or contuse the tissues[1].

After the removal of the elastic ring no focal problems were found, such as bruises, petechias, chemical burns as in the use of pneumatic tourniquet[4]. We should mention the presence of minor skin signs resembling the signs that a stocking leaves in the skin, which disappear in less than an hour. The elastic tourniquet applies pressure to a small skin surface, apparently much smaller than the surface pressed by the pneumatic tourniquet. As a result of this, we did not find any neurological deficits described with the traditional method[5].

We preferred to use the ring at the upper arm level or at the thigh to avoid the possibility of postoperative infection from contamination of the surgical field. Some authors have accused pneumatic tourniquet for infection by methicillin resistant staphylococcus aureus (MRSA)

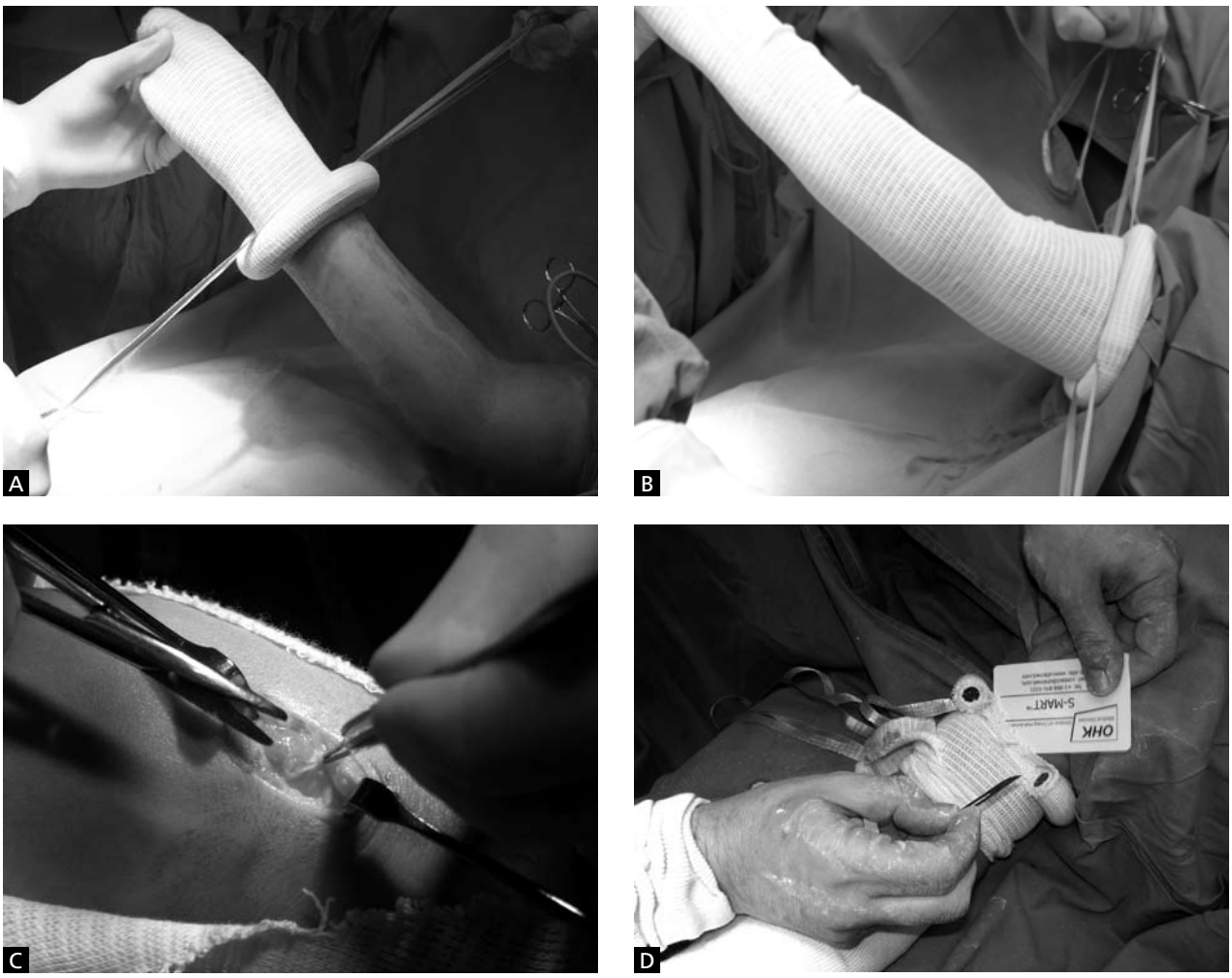

Figure 2. Application of the sterile tourniquet in an upper limb with a carpal ganglion. **A)** It is placed on the patient's fingers by the orthopaedic surgeon, with the surgical field being previously appropriately prepared. **B)** Pulling the straps vertically to the longitudinal axis of the limb, the elastic ring rolls up the limb quickly and without effort until its end point of application. **C)** We open (or remove) with scissors the part of the stockinet that covers the incision site. **D)** After the end of the operation the elastic ring can be cut with the use of a scalpel size no.21 with the help of a special plastic card.

due to its progressive migration during the operation[3,7,8]. No cases of deep venous thrombosis or compartment syndromes were found.

CONCLUSIONS

Sterile tourniquet bandage is a device that combines easy with quick application, decreases the exsanguination time, provides an excellent sterile surgical field and can be used in situations where pneumatic ones are not feasible. As it is applied by the surgeon, its use obviates the need for a technician to secure the tourniquet and make all the calibrations. It can be replaced easily when the operation lasts more than 90 minutes and is free of soft-tissue, vascular or neurological side effects. However its pressure remains stable (it can not be altered operatively) and can not be used in operations that last over 90 minutes with insufficiency in unstable fractures or dislocations. Summarizing, we could say that we report in this study the superior effectiveness of this device over the traditional method without posing additional problems.

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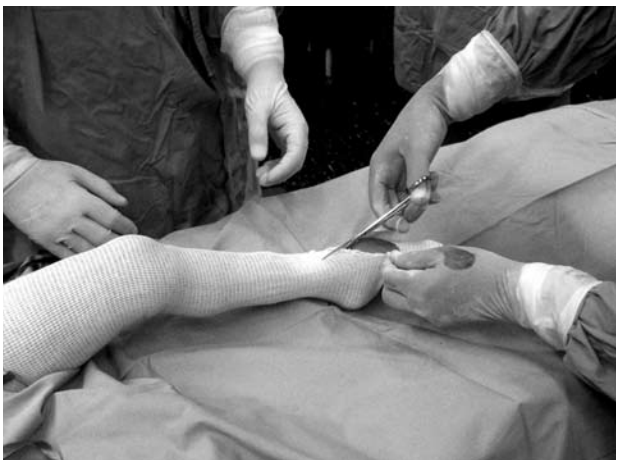

Figure 3. Scrub nurse was complaining about the use of the sterilized scissors to open the applied stockinet in the beginning of the operation.

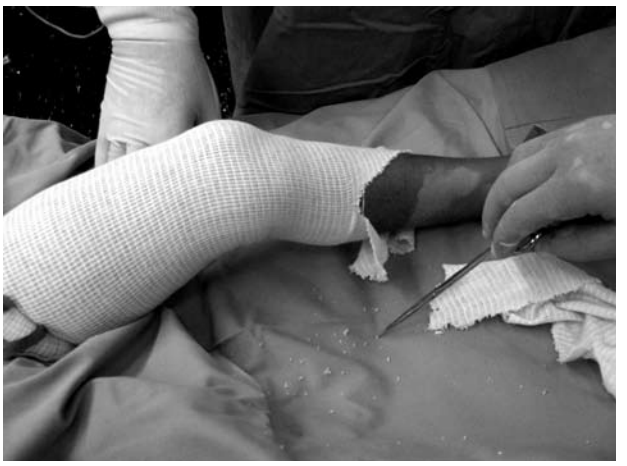

Figure 4. Scrub nurse was concerned about the presence of free particles of cut stockinet near the surgical field which were difficult removed.

Table 2.

Evaluation criteria	Result
1. Ease of application	very satisfying
2. Time for application	less than 60 seconds
3. Tourniquet position on the limb	proximal end of humerus or femur
4. Quality of exsanguination-bleeding upon first incision	Excellent
5. Quality of exsanguination during the whole procedure	Excellent
6. Interference with surgical field	not mentioned
7. Joint mobility distal and proximal to the tourniquet	Free
8. Ease of removal	very satisfying
9. Scrub nurse's opinion	Reserved
10. Postoperative complications	not mentioned

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