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ORIGINAL ARTICLE

Impact of a tourniquet type on outcomes in ORIF of paediatric distal radius fractures

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ABSTRACT

Aim To assess benefits of utilizing a silicone ring tourniquet in relation to traditional pneumatic cuff tourniquets, and scenarios without any tourniquet intervention. The tested hypothesis was that clinical results could be increased after the use of the silicone ring tourniquet.

Methods The study was monocentric and retrospective evaluation of collected data. An inclusion criterion was open reduction and internal fixation of a displaced distal radius fracture in pediatric population (6-12 years). The pneumatic tourniquet (PT) group involved 18 patients, the no tourniquet group (NT) 19 patients and the silicon ring (SR) group 19 patients. All patients were followed for 6 months. The VAS score at 1 day and 7 days postoperatively was primary outcome. The secondary outcome was a delay of discharge, time of surgery and occurrence of complications.

Results The VAS score in the first and seventh postoperative day was 3.8±1,0 and 2.0±0.5, for the PT group, 3.5±0.5 and 1.8±0.2 for the NT group and 3.2±0.8 and 1.8±0.4 for the SR group, respectively, without statistically significant differences ($p>0.1$). There was a non-significantly higher rate of complications for PT group, especially for skin complications, and a higher time of surgery in the NT group.

Conclusion The proposed hypothesis was not validated, as there were no notable changes observed in the clinical outcomes. Additionally, the analysis of complications revealed no evidence of bias. However, the reduced prevalence of skin complications may indicate a beneficial effect associated with the silicone ring tourniquet.

Keywords: hemaclear, paediatric, pneumatique, Tourniquet

INTRODUCTION

Tourniquets are frequently employed in orthopaedic procedures, offering recognized advantages alongside inherent risks. A systematic review conducted in 2021 (1) examined the existing evidence related to the tourniquet use in orthopaedic surgery for children aiming to inform safe clinical practices. The habitual application of tourniquets for both elective surgeries and fracture fixations lacks solid evidence regarding their benefits and potential complications (1). Distal radius fractures represent a prevalent injury in children, constituting approximately 30% of all paediatric fractures (2).

Closed reduction and casting remain the first-line treatment for most paediatric distal radius fractures, given the significant healing capacity and a remodelling potential in children (3). The surgical option for these fractures has become increasingly more usual for different reasons like socioeconomic changes, liability apprehensions, and family and surgeon intolerance of residual deformity (4).

The use of pneumatic tourniquets in paediatric patients with upper extremity fractures can be particularly challenging. Factors such as the small size of the limb may limit the available space for proper placement of the tourniquet on the upper arm (5). Moreover, many tourniquets can shift too close to the surgical area, which risks compromising sterility (6). Additional complications related to pneumatic tourniquets, which are not exclusive to paediatric cases, include chemical burns, skin abrasions, and potential mechanical malfunctions (1).

Due to the limitations of pneumatic tourniquets, Esmarch bandages have emerged as a viable alternative. These bandages are reusable, easy to disinfect, and effective for blood exsanguination, irrespective of the patient's limb size. However, their broader cuffs can make it challenging to control the pressure at the application point, which may lead to potential tissue damage (7). As a result, sterile silicone ring tourniquets have been proposed as a better option. With narrower 2 cm cuffs, these devices offer uniform pressure across the compression area and can be applied in a sterile environment in the upper or lower limb for different procedures (6,8).

Although tourniquets are frequently used in paediatric orthopaedic surgery, there is no universally accepted protocol tailored specifically for children. Surgeons typically rely on

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guidelines aimed at minimizing ischemic injury and controlling pressure, alongside close monitoring to prevent complications (9). The choice to use a tourniquet is influenced by factors such as the child's age, the nature of the surgery, and the surgeon's expertise. Ongoing research is focused on developing more refined guidelines and understanding outcomes in pediatric cases (8).

In the absence of clear guidelines, different non standardized methods of tourniquet in paediatric orthopaedic procedures are used. However, there are no comparative studies on the use of silicone ring tourniquet in a single orthopaedic procedure on paediatric patients.

The aim of the present study was to evaluate potential advantages of a silicon ring tourniquet in comparison to the conventional pneumatic cuff tourniquet or no tourniquet used during open reduction and internal fixation (ORIF) of paediatric distal radius fractures. The tested hypothesis was that the clinical results be increased after the use of the silicone ring tourniquet.

PATIENTS AND METHODS

Patients and study design

A retrospective review of printed and digital medical records from Vito Fazzi Hospital of Lecce archives was conducted. The cohort consisted of 62 patients aged 6-12 years who underwent open reduction and internal fixation for distal radius fractures in the Vito Fazzi Hospital of Lecce (Italy) from 2015 to 2023.

Inclusion criteria were a distal radius fracture, angulation greater than 30°, malrotation exceeding 20°, or bayonetting of more than 1 cm after closed reduction, ages 6-12 years, no pre-operative neurovascular injury, and a follow-up duration exceeding 11 months. Exclusion criteria were: other fractures or dislocations of the upper extremity, pathological fractures, open fractures, fractures with neurovascular injury, re-fractures, and complex forearm fractures (such as Monteggia or Galeazzi fractures, or intra-articular elbow or wrist fractures). Ultimately, six patients were excluded from the analysis (four were unavailable for follow-up, and two had concurrent humeral fractures) resulting in a final study group of 56 patients.

Data collected from the patients consisted of gender, age, height, weight, time from injury to surgery, surgical time, perioperative complications, Visual Analogue Score (VAS) (10) at 1 and 7 days, and final results. Complications recorded consisted of infections, bruises, neurological deficits, malunion, and nonunion.

Three groups of patients were assigned. The pneumatic tourniquet (PT) group involved 18, the no tourniquet (NT) group 19 and the silicon ring (SR) group 19 patients. All patients were followed for 6 months. Primary criterion was the VAS score at day 1 and 7 days postoperatively. Secondary criteria were a delay of discharge, time of surgery and occurrence of complications.

The Ethics Committee of Comitato Etico Istituto Tumori di Bari approved the study. An informed consent for surgery was obtained from parents of all patients.

Methods

Under general anaesthesia all patients underwent an open reduction and fixation of the fracture with a volar plate through a volar approach and the choice of tourniquet based on the surgeon's preferences.

Silicon ring group (SR). In the SR group the HemaClear device (OHK Medical Devices, Haifa, Israel) (Figure 1) features a silicone ring encased in a stockinet sleeve, equipped with pull straps. It serves three key purposes: removing blood (exsanguination), occluding arterial flow, and positioning a sterile stockinet. The ring was applied to the limb, and the straps were drawn proximally. As the ring rolled up the limb, the stockinet sleeve unfolded over it. This rolling action allows the ring to apply pressure, effectively pushing blood away from the limb. Notably, the design utilizes just a single silicone ring, resulting in a compact profile.

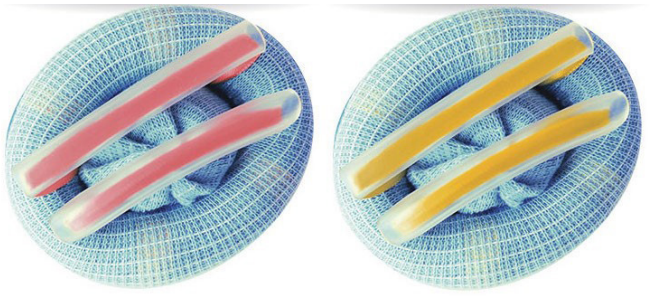

Figure 1. HemaClear device (OHK Medical Devices, Haifa, Israel)

Pneumatic tourniquet (PT) group. In the PT group, the pneumatic tourniquet (Ulrich Medical, UT 1330 S, Ulm, Germany) (Figure 2) was positioned over four layers of orthopaedic wool, as high as possible on the arm. A size 45/9 pneumatic cuff was then inflated to a pressure 50 mmHg above the patient's systolic blood pressure.

Figure 2. Pneumatique tourniquet device (Ulrich GmbH & Co. KG, Buchbrunnenweg Germany)

No tourniquet (NT) group. In the NT group a classic surgical field with sterile drapes up to the elbow was prepared. After the surgical incision and before closure a careful haemostasis with electrocautery was performed.

After surgery a short arm splint fixation was applied to all patients for three weeks. One shot prophylactic antibiotic therapy was administered 1 hour before surgery and pain control without opioid. Radiological results of the patients were followed up at regular post-operative intervals (Figure 3).

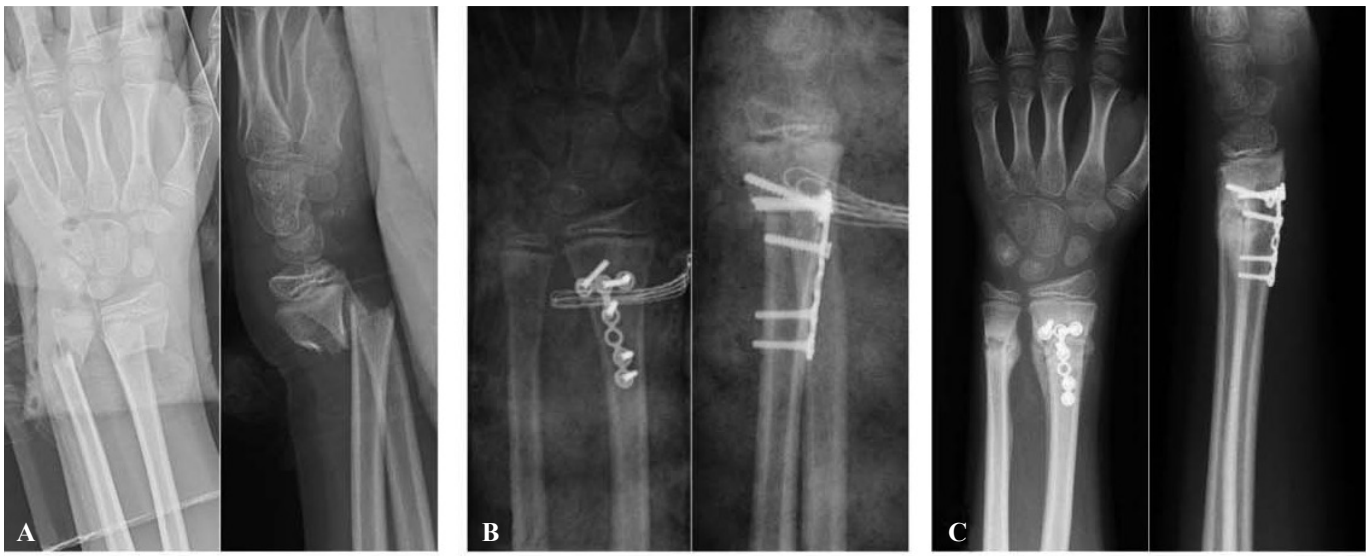

Figure 3. X-ray of a clinical case A) preoperatively; B) immediate postoperatively; C) 6 months postoperatively (Vito Fazzi Hospital, 2021)

Statistical analysis

Categorical variables were expressed as numbers and percentages, while continuous variables were shown as mean±SD (standard deviation). For the comparisons among three groups, a one-way analysis of variance (ANOVA) was utilized, followed by Tukey's post hoc test for further analysis. A $p<0.05$ was considered statistically significant.

RESULTS

No significant differences were found between 3 groups in terms of age, gender, height, weight and time from injury to surgery (Table 1).

Table 1. Demographic data of the three patient groups

Variable	Pneumatic tourniquet	No tourniquet	Silicon ring	p
Number of patients	18	19	19	
Age at time of the surgery (Mean±SD)	9.00±2		9±3	>0.1
Gender (No; %)				>0.1
Male	11(61.1)	13 (68.4)	14 (3.6)	
Female	7 (38.9)	6 (31.6)	5 (26.4)	
		Mean±SD		
Height	132.6±5	130.1±4	133.4±3	>0.1
Weight	40.1±4	38.5±4	39.1±4	>0.1
Injury time to surgery	1.10±0.6	1.12±0.5	1.00±0.3	>0.1

The VAS score in the first and seventh postoperative day was 3.8±1 and 2.0±0.5 for the PT group, 3.5±0.5 and 1.8±0.2 for the NT group and 3.2±0.8 and 1.8±0.4 for the SR group, respectively, without statistically significant differences ($p>0.1$). The surgical time was slightly inferior in the SR group but no statistical difference was found ($p=0.5$) (Table 2).

No complications were recorded in the NT and SR group. In the PT group one (5.5%) case of superficial bruise in the upper arm tourniquet area was recorded. The bruise healed without treatment within 10 days. In two (11%) cases the pneumatic tourniquet failed to give a bloodless field, raising the time of surgery. In one case the tourniquet was completely deflated and re-inflated with good results. In the other case the surgeon preferred to continue without tourniquet (Table 3).

Table 2. Clinical results of the three patient groups

Variable	Mean±SD in the group			p
	Pneumatic tourniquet	No tourniquet	Silicon ring	
VAS score				
day 1	3.8 ±1	3.5 ± 0.5	3.2 ± 0.8	0.1
ore day 7	2.0 ± 0.5	1.8 ± 0.2	1.8 ± 0.4	0.1
Surgical time (minutes)	48 ± 10	44 ± 4	42 ± 3	0.1

Table 3. Complications of the three patients groups

Complication	No (%) of patients in the group		
	Pneumatic tourniquet	No tourniquet	Silicon ring
Bruises (superficial)	1 (5.5)	0	0
Failures (tourniquet during surgery	2 (11)	0	0
Infections	0	0	0
Neuropathy	0	0	0
Malunions	0	0	0

DISCUSSION

Currently, there are no universally established guidelines specifically for the use of tourniquets in paediatric orthopaedic surgery. Recommendations are primarily based on expert judgment, hospital protocols, and existing literature, often adapting adult practices to fit paediatric needs (8). Paediatric orthopaedic surgeons typically follow general principles aimed at reducing ischemia and nerve injury, while also managing the need for haemostasis during surgery.

The use of tourniquets in paediatric upper limb orthopaedic surgery is a topic of ongoing debate, as it presents both potential advantages and risks (5).

Tourniquet use may lead to several adverse effects and complications, including alterations in physiological metrics like

blood pressure, heart rate, and core body temperature (11). Additionally, biochemical shifts can induce a mixed state of respiratory and metabolic acidosis (12). These physiological changes can be attributed to the redistribution of blood flow, localized pressure injuries, and limb ischemia, which causes skeletal muscle to shift to anaerobic metabolism, resulting in an increased lactate production (13).

Different studies documented instances of nerve damage (14,15), while additional anecdotal reports highlighted other adverse events, including an elevated risk of thrombotic incidents (16), fat embolism (17), and compartment syndrome (1). This study did not record that kind of complications and the clinical results compare with VAS score at days 1 and 7 postop did not show significant differences between different groups. Skin burns can occur when disinfectant accumulates beneath the tourniquet, representing a preventable complication that can be avoided with proper application techniques (18). In this study in the PT group one case of superficial bruise in the upper arm tourniquet area was recorded.

In most cases Tourniquet duration is primarily influenced by the length of the surgical procedure, which varies based on the type and complexity of the operation. Previous studies have indicated a link between significant complications and tourniquet times exceeding 114 minutes (19). The time of surgery for open reduction and internal fixation of distal radius fracture was less than an hour in all cases in our research.

While the main objectives of using tourniquets during surgery are to enhance visibility and reduce blood loss, there is a lack of direct studies comparing the quality of the surgical field with and without tourniquet application. Only one study addressed the variation in blood loss, and its findings indicated no clinically significant difference (20). To our knowledge this is the first study to compare the clinical results of different tourniquet type in a single orthopaedic upper limb procedure in paediatric population.

However, this study has different limitations. It is a retrospective study which may introduce bias due to reliance on existing medical records and the potential for incomplete or inaccurate data. The number of patients in each group is relatively small (18 in PT, 19 in NT, 19 in SR), which may affect the statistical power to detect significant differences between the groups. The circumference of the limb is a parameter that was not recorded and could influence the homogeneity of the groups. However, height, weight and age of the patients were similar for the 3 groups. With only six months of follow-up, the study may not capture long-term outcome or complications that could arise later. Nonetheless, the majority of complications related to tourniquet use tend to manifest shortly after the application, indicating that a brief follow-up period could yield meaningful findings. The type of plate fixation or number of screw was not considered as well as the presence of a distal ulnar fracture. However, no procedures were performed for eventually ulnar fracture.

These limitations suggest the need for further studies with larger, multicentric, and randomized designs to validate the findings and explore the efficacy of different tourniquet types in paediatric surgeries.

In conclusion, this study suggests that the routine use of tourniquets in paediatric distal radius fracture surgery may not be necessary, and the SR tourniquet did not show significant benefits over the no tourniquet in terms of pain management and complications. Notably, the absence of complications in both the no tourniquet group and silicon ring group supports the consideration of less invasive practices in paediatric orthopaedic upper limb surgery.

All authors (1,2,3,4,5,6,7) confirm that the manuscript has been submitted solely to this journal and is not published in press, or submitted elsewhere (including preprint servers). Authors confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship.

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TRANSPARENCY DECLARATION

Conflict of interest: None to declare.

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