



Pneumatic Tourniquet in Pediatric Surgery - Is it not Time to Break the Pressure of Habits?

Chrystelle Sola^{1,2*}, Mamadou Mour Traore^{1,3}, Julien Pico^{1,2}, Lucie Coruble¹, Jérémie Castanié¹, Marion Delpont⁴ and Christophe Dadure^{1,2}

¹Department of Anesthesia and Critical Care Medicine, Montpellier University, France

²Department of Anesthesia and Critical Care Medicine, Institute of Functional Genomics, France

³Department of Anesthesia and Critical Care Medicine, Cheikh Anta Diop University, Senegal

⁴Department of Pediatric Orthopedic Surgery, Montpellier University, France

Abstract

Purpose: Pneumatic tourniquet is commonly used in limb surgery including in pediatric population. Despite the potential benefits on operating condition, its use is not without risk and can lead to disastrous adverse effects. In daily practice, tourniquet cuff pressures are commonly set arbitrary at standard pressures, based on empirical formulas or surgeon's experience or habits. In children, anatomical and physiological characteristics are rarely taken into account. This preliminary study aimed to evaluate the impact of a low tourniquet cuff pressure setting on operative field quality and surgical satisfaction.

Methods: All children less than 16 years of age scheduled for elective extremity surgery were consecutively included. The tourniquet cuff pressure was defined on the base of the child's baseline systolic blood pressure increased by 50 mmHg. At the same time, the surgeon, who remained blind on the tourniquet cuff pressure applied, was asked to indicate the desired cuff pressure according to the usual individual practice. At the end of procedure, operative field quality and surgical satisfaction were collected. The applied tourniquet pressure was compared with the cuff pressure desired by the surgeons.

Results: Thirty-two children (10 ± 4.5 years, 39 ± 20 kg) were included. The mean cuff pressure desired by surgeons was 207 ± 37 mmHg. In comparison, tourniquet cuff pressure applied was 146 ± 11 mmHg (difference in means: ΔTP: 28% [CI 95% 26-33%], p<0.001). The mean surgical satisfaction score referring to the quality of the operative field and operative conditions was 9 ± 1 with an excellent or good surgeon satisfaction in 100% of cases.

Conclusion: In children up to 16 years, adjustment of tourniquet cuff pressure 50 mmHg above the baseline systolic blood pressure has resulted in a reduction of almost 30% of the cuff pressure compared to current practice without compromising the quality of the operative field. These preliminary data suggest the possible use of low tourniquet cuff pressure in children and the need to promote guidelines on the best practices for safer use of pneumatic tourniquet in pediatric surgery.

Keywords: Pediatric anesthesia; Pediatric surgery; Tourniquet cuff pressure; Peri-operative medicine

Introduction

Pneumatic tourniquet is commonly used in limb surgery to improve operating conditions, maintain a bloodless surgical field and reduce perioperative bleeding. Despite these well-known benefits, its use is not without risk and can lead to serious adverse effects. The application of tourniquet is associated with unwanted significant local (nervous, muscular, vascular, and cutaneous) and systemic (cardiovascular, respiratory, metabolic) consequences which should not be neglected [1]. In order to reduce tissue damage and ischemia-reperfusion injuries, it is widely recommended to apply the lowest Tourniquet cuff Pressure (TP) as possible and limit the inflation time [2,3]. In daily practice, including in pediatric patients, tourniquet cuff pressures are commonly set at standard pressures, based on empirical formulas or surgeon's experience or habits. The anatomical and physiological characteristics related to age and growing process are rarely taken into account: muscle mass and those of other soft tissues are considerably lower and vary according to the stage of development. Extrapolation of adult practices to the pediatric population appears

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*Correspondence:

Chrystelle Sola, Department of Anesthesia and Critical Care Medicine, Montpellier University, Institute of Functional Genomics, 371 Avenue du Doyen Gaston Giraud, 34295 Montpellier, France, Tel: 00 33(0)467338256; Fax: 00 33(0)467337960; E-mail: c-sola@chu-montpellier.fr

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therefore inappropriate and potentially dangerous. This preliminary study aimed to evaluate the impact of a low tourniquet cuff pressure setting on the quality of the bloodless field and surgeon satisfaction.

Material and Methods

This observational single blind study was conducted at a single academic institution (Lapeyronie University Hospital, Montpellier, France). After information and parental consent, all children less than 16 years of age scheduled for elective extremity surgery were consecutively included. Exclusion criteria included any absolute or relative contraindications to the use of a surgical pneumatic tourniquet.

Anesthetic management and research protocol

According to common practice in pediatric anesthesia, surgeries were performed under general anesthesia associated or not with regional anesthesia depending on the type of procedure. Standard intra-operative monitoring included automatic electrocardiogram, non-invasive arterial blood pressure measure, pulse oximetry, end-tidal carbon dioxide concentration, and sevoflurane inspiratory/expiratory fractions. Anesthesia modalities were left to the discretion of the anesthesiologist in charge of the patient. All patients received per operative systemic analgesia using paracetamol and ketoprofen in absence of contraindication.

The Tourniquet cuff Pressure (TP) was determined based on the child's baseline Systolic Blood Pressure (SBP), measured just before anesthetic induction, increased by 50 mmHg. The tourniquet pressure was applied blindly from the surgeon using an electronic pneumatic tourniquet with 2 regulated pressure circuits (Easy Pump[®]-Dessillons & Dutrillaux, France). At the same time, the surgeon was informed about the child's current and baseline systolic blood pressure and asked to indicate the desired cuff pressure according to the usual practice. During procedure, in case of poor quality of the bloodless field, the applied TP may be increased by increment of 25 mmHg at the request of the surgeon.

Collected data

For each included patient, demographic data, type of surgery and anesthetic modalities were collected. The surgeon remained blind to the applied inflation tourniquet pressure. At the end of the procedure, the duration and definitive tourniquet pressure were collected and the surgeon immediately asked to rate the quality of the bloodless field and the level of satisfaction on surgical comfort. Potential complications related to the tourniquet use were investigated until the postoperative 24th hour.

Statistical analysis

The primary outcome of the study was the difference between applied tourniquet pressure (baseline SBP + 50 mmHg) and cuff pressure based on surgeon's usual practice. The secondary endpoints included surgical comfort assessed by the quality of the bloodless field rate on an analogical visual scale (0-10) and by the level of surgeon satisfaction (poor-medium-good-excellent). Complications related to the use of pneumatic tourniquet were also recorded. Correlations between desired tourniquet cuff pressure and demographic characteristics were analyzed by Simple Linear Regression. A priori sample size calculation was determined: a minimum of 24 patients are required to have a 90% chance of detecting, at the 5% significance level, a clinically significant 20% difference between the cuff pressure based on the usual practice of the surgeon and the cuff pressure

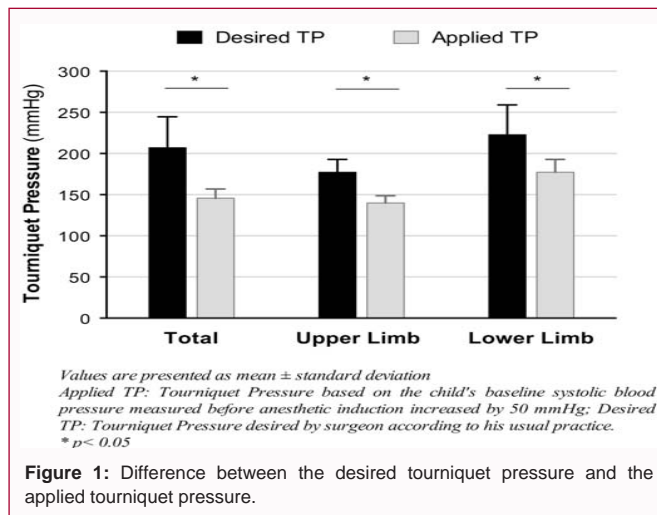


Figure 1: Difference between the desired tourniquet pressure and the applied tourniquet pressure.

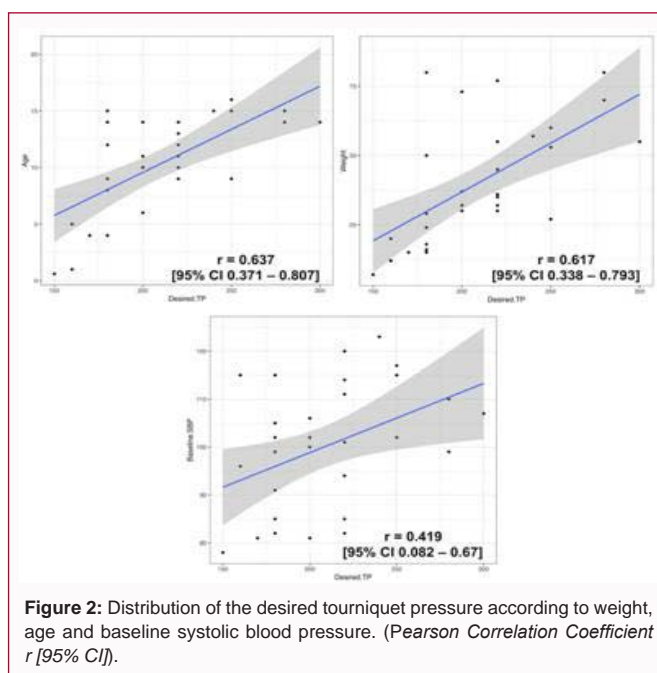


Figure 2: Distribution of the desired tourniquet pressure according to weight, age and baseline systolic blood pressure. (Pearson Correlation Coefficient r [95% CI]).

applied on base of systolic blood pressure. Thirty-two patients were included in the study to allow for potential protocol violations and dropouts. The results are presented as mean (± standard deviation). Comparison of the quantitative variables was performed using the Student's t-test and the 95% confidence intervals calculated. A value of p<0.05 was considered significant. All analyzes were done using SAS 8.02 software (SAS Institute, Cary, North Carolina).

Results

A total of 32 patients (age: 10 ± 4.5 years, weight 39 ± 20 kg) were included in the study. The lower limb was involved in 65% of surgical cases. The details of demographic characteristics are reported in Table 1.

The mean TP according to the usual practice of surgeon and TP applied on base of baseline SBP were respectively 207 ± 37 and 146 ± 11 mmHg (difference in means: ΔTP: 62 [IC 95% 50-74] mm Hg, p<0.001). In the upper limb group, TP desired surgeons compared 177 ± 15 with 140 ± 8 mmHg on base of baseline SBP. In the lower limb group, TP desired surgeons compared 223 ± 35 with 149 ± 11

Table 1: Demographic Characteristics.

	Upper limb surgery (n=11)	Lower limb surgery (n=21)	Total (n=32)
	8 ± 5	11 ± 4	10 ± 4
Gender M/F (%)	6 (55)/5 (45)	15 (71)/6 (29)	21 (66)/11 (34)
	31 ± 22	43.5 ± 21	39 ± 22
Regional Anesthesia (%)	6 (55)	18 (86)	24 (75)
Surgical procedure			
- Plastic surgery	4 (36.5)	-	4 (12.5)
- Osteotomy	4 (36.5)	7 (33)	11 (34)
- Osteosynthesis implant removal	3 (27)	5 (24)	8 (25)
- Hallux Valgus correction	-	3 (14)	3 (9.5)
- Clubfoot repair	-	4 (19)	4 (12.5)
- Knee arthroscopy	-	2 (10)	2 (6.5)
Baseline SBP (mmHg)	96 ± 13	102 ± 13	100 ± 13
Tourniquet Time (min)	50 ± 41	63 ± 45	58 ± 44

Values are expressed as mean ± standard deviation and n (%)
 SBP: Systolic Blood Pressure

mmHg on base of baseline SBP (p<0.001). The difference in means was statistically significant for upper limb (ΔTP: 37 [95% CI 26-48] mmHg, p<0.001) as well as for lower limb surgeries (ΔTP: 75 [IC 95% 58-92] mmHg, p<0.001). The decrease on tourniquet cuff insufflation pressure reached 28% ([95% CI 26-33], P<0.001). Details for upper end lower limbs are illustrated in Figure 1.

As describe in Figure 2, linear regression analysis found a weak correlation between the TP applied according to the usual practice of surgeon and Age (r²=0.41) or Weight (r²=0.38) and poor correlation with baseline SBP (r²=0.175).

The average application time of the tourniquet was 58 ± 44 min. For one patient, surgical discomfort required increasing TP from 130 to 155 mmHg. This case involved a foot surgery in a 4-years-old child weighing 15 kg with a low baseline SBP measured at 80 mmHg. Surgeon desired TP was 170 mmHg. Any intra operative hemodynamic variation was found to explain the lack of tourniquet efficiency.

The mean surgical comfort score referring to the quality of the operative field and operative conditions was 9 ± 1. Finally, operator satisfactions were excellent or good in respectively 78% and 22% of cases. No complication related to the use of the tourniquet has been reported at the 24th post-operative hour.

Discussion

In children up to 16 years, adjustment of tourniquet cuff pressure 50 mmHg above the baseline systolic blood pressure has resulted in a reduction of almost 30% of the cuff pressure compared with current local practice. The use of lower cuff pressures compromised neither the quality of the operating field nor the surgical satisfaction. These data suggest the efficiency of low tourniquet pressures setting in children. The development of multidisciplinary Guidelines to reinforce awareness and understanding in the use of pneumatic tourniquet in pediatric surgery would provide greater safety and decreased potential risks.

The use of tourniquet in surgery remains very common, including in pediatrics, despite its well-known adverse effects and the inherent risk of complications, rare but potentially disastrous. The consequences of tourniquet setting up on the limb result in local,

regional and systemic effects. At the cuff-positioning zone, lesions are both mechanical, by compression of the underlying tissues, and ischemic, by interruption of the arterial blood flow downstream of the cuff. Some nerve damage ranging from paresthesia to complete paralysis, muscle damage extending from rhabdomyolysis to authentic compartment syndrome, as well as abrasions, burns or cutaneous necrosis have been reported [4-6]. These complications appear to be related to insufflation pressure used and tourniquet time. Systemic hemodynamic, respiratory and metabolic effects are the direct witness of the adaptive response of the organism [7]. The prevention and reduction in number of side effects and the nature and extent of tourniquet damage require correct knowledge of safety practices, especially on setting the minimum efficient cuff pressure and on inflation time limits. Despite recommended practices [8]. Tourniquet pressure setting, based on habits or empirical formulae, without taking into account of the numerous individual variables (i.e., patient age, blood pressure, size of extremity), remains common in daily practice. As illustrated by our results, a weak correlation was found between individual patient characteristics and the cuff pressure arbitrary selected by surgeon. This strategy most often resulted in a tourniquet pressure much higher than required to produce a bloodless surgical field.

In order to optimize the cuff pressure level, the American Association of peri-operative Registered Nurses (AORN) recommends the use of limb occlusion pressure measurement (Limb Occlusion Pressure: LOP) as a reference method [9]. LOP is defined as the lowest tourniquet pressure required to stop arterial blood flow downstream of the cuff. This individualized pressure appears very easily to measure in daily clinical practice by the disappearance of the peripheral pulse of the limbs using simple palpation, a Doppler or a simple oximetry pulse sensor. For adults, according to the value of the LOP, a safety margin is added as follow: + 40 mmHg if the LOP is <130 mmHg, +60 mmHg if the LOP is between 130 and 190 mmHg, and + 80 mmHg if the LOP is >190 mm Hg [9]. In comparison with the usual method or a standard setting up, a significant reduction in tourniquet pressure was reported in adult population when the LOP measurement is performed [10,11]. In pediatric population, data are very scarce but similar results have been reported in 10 to 17 years old children undergoing anterior cruciate ligament repair. Reilly

et al. [12] found a significant decrease in the average cuff pressure between the control group (standard pressure setting at 300 mmHg) and the limb occlusion pressure group (151 mmHg; $p < 0.001$) [12]. AORN's guideline suggests adding 50 mmHg to the measured LOP in pediatric patients based in part on the results of Lieberman et al. [13] study. In this last, authors found that when using limb occlusion pressure plus 50 mmHg to set cuff pressure, adequate hemostasis may be achieved in 86% of cases at lower pressures than those commonly used. Among the 29 cases (age ranging from 4 month to 17 years), LOP based tourniquet pressure were 170.8 ± 13.3 and 168.8 ± 21.1 mmHg in upper and lower extremity group respectively [13]. In concordance with Reilly et al. [12] we reported a mean cuff pressure of 149 ± 11 mmHg in the lower limb group. Moreover, in comparison with the Lieberman's study, we shown lower efficient cuff pressure in both upper and lower extremity groups with a quality of operative fields reported in 99% of cases In the present work, we chose to optimize the tourniquet pressure by applying a minimum safety margin (+ 50 mmHg) above the baseline systolic blood pressure. Although the method of LOP measurement was not used, our results are in agreement with adult and pediatric previous studies using LOP measure. We reported an optimal surgical comfort at nearly 30% lower pressures than those commonly used. A number of limits should be emphasized. Our sample is relatively small and numerous different surgical procedures involving both upper and lower limbs were included. Moreover, if our results are concordant with previous literature in pediatric population, the pre-anesthetic systolic blood pressure, rapid and easy to perform in daily practice, remains questionable to set the tourniquet pressure. Indeed, in adults population, a low correlation between LOP and systolic blood pressure has been reported. In addition, the LOP is measured after the anesthetic induction and final installation of the patient, under close conditions to those of the operating time. Future research should test the value of these results through a wide pediatric population and determine the optimal technique for a proper and safe surgical tourniquet use in pediatric surgery.

Conclusion

This work confirms that the use of minimal personalized tourniquet cuff pressure on children produce an effective quality of the operating field. If the optimal method for safer use of surgical tourniquet in pediatrics remains to be defined, it remains essential to promote awareness of professional on best practices for safer use of pneumatic tourniquet in pediatric surgery.

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