Clinical pain research

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Pressure pain thresholds in children before and after surgery: a prospective study

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Abstract

Background and aims: This prospective study aimed to assess pressure pain thresholds (PPTs) by pressure algometry and the correlation to postoperative pain in children undergoing orthopaedic surgery. We hypothesized, that the PPTs would decline immediately after elective orthopaedic surgery and return to baseline values at follow-up.
Methods: Thirty children aged 6–16 years were included. PPTs and intensity of pain (Numerical Rating Scale, NRS) were assessed 3–6 weeks before surgery (baseline), 1–2 h before surgery (Day 0), the first postoperative day (Day 1) and 6–12 weeks after surgery (Follow-up).
Results: A significant difference of PPTs between the four assessments was seen using the Friedman test for detecting differences across multiple tests and Wilcoxon signed-rank test with a Bonferroni adjustment. The changes in PPTs between baseline ($PPT_{crus}=248$ kPa, $PPT_{thenar}=195$ kPa) and day 1 ($PPT_{crus}=146$ kPa, $PPT_{thenar}=161$ kPa) showed a decline of PPTs as hypothesized ($Z_{crus}=2.373$, $p=0.018$; $Z_{thenar}=0.55$, $p=0.581$). More surprisingly, a significant decrease in PPTs between baseline and day 0, just before surgery ($PPT_{crus}=171$ kPa, $PPT_{thenar}=179$ kPa), was also measured ($Z_{crus}=2.475$, $p=0.013$; $Z_{thenar}=2.414$, $p=0.016$). PPTs were positively correlated to higher age, weight and height; but not to NRS or opioid equivalent use.
Conclusions: Children undergoing orthopaedic surgery demonstrate significant changes in PPTs over time. The PPTs decrease significantly between baseline and day 0, further decreases the first day postoperatively and returns to baseline values at follow-up. This suggests that other factors than surgery modulate the threshold for pain.
Implications: Awareness of pressure pain thresholds may help identify children with affected pain perception and hence improve future pain management in children undergoing orthopaedic surgery. Factors as for example anticipatory anxiety, psychological habitus, expected pain, catastrophizing, distraction, physical activity, patient education and preoperative pain medication might play a role in the perception of pain and need further investigation.

Keywords: pressure algometry; pressure pain threshold (PPT); children; orthopaedic surgery.

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1 Introduction

The perception of pain in children undergoing orthopaedic surgery can be determined by the individual child's threshold for pain. Pressure pain threshold (PPT) is defined as the amount of pressure that is perceived as pain, rather than discomfort and is different from the tolerance threshold for pain. Pain thresholds can be measured quantitatively by pressure algometry, which allows application of pressure under standardized conditions. PPTs are well documented for use in adults and children as a psycho-physical measure of pain sensitivity from deep tissue [1, 2].

Pressure algometry has been validated for use in adults [3–5] and in recent years, the method has been further validated for use in children [1, 2, 6–10]. In healthy children, Nikolajsen et al. [1] have found excellent intrarater agreement and satisfactory interrater agreement for the assessment of PPTs using pressure algometry. Several studies have investigated the PPTs in both adults and children with a chronic condition as for example cerebral palsy, hypermobility syndrome juvenile fibromyalgia, children with growing pains, headache or autism spectrum disorders and adults with chronic back pain [7, 11–16]. It is shown that preoperatively assessed factors such as pressure pain sensitivity, age, sex, anxiety, preoperative pain and type of surgery are predictive of the level of postoperative pain [8, 17]. Studies indicate that children's postoperative pain level can be predicted by presurgical expectations and anticipatory emotions [18].

Acute postoperative pain is caused by tissue and nerve trauma causing hyperexcitability in the nociceptive pathways [8]. Since the assessment of pain thresholds can detect changes in excitability of tissue, we hypothesized that the PPTs in children would decline immediately after elective orthopaedic surgery and return to baseline values at follow-up. The indications for orthopaedic surgery in children are predominantly biomechanical, congenital or traumatic injuries causing disability or pain. Continuous assessments of PPTs in children during the entire orthopaedic surgical process have to our knowledge not yet been undertaken. Hence, a prospective study was set up to assess PPTs and intensity of pain in children during elective orthopaedic surgery aiming to describe the development of PPTs over time. The primary outcome was the difference of PPTs between baseline and the first postoperative day (Day 1). The PPTs at baseline, the day of surgery (Day 0), day 1 and at follow-up are also presented.

Table 1: Baseline demographics.

Number of children, n	30
Age, years, (range)	11 (6–16)
Sex (M/F)	12/18
Height, cm, (range)	151 (110–182)
Weight, kg, (range)	47 (22–98)
Orthopaedic diagnosis, n (%)	
Congenital bony deformity	4 (13)
Foot deformities (Flat foot, club foot, coalitio)	12 (40)
Neuromuscular disease (Syringomyelia, Charcoot-Marie-Tooth)	3 (10)
Hip disease (Calve-Legg-Perthes disease, congenital femoral anteversion)	6 (20)
Other (Heriditary Multiple Exostosis, Mb. Olliers, fibular dysplasia)	5 (17)
Surgical procedures, n (%)	
Osteotomy (femoral, tibial)	9 (30)
Calcaneal lengthening	7 (23)
Other (soft tissue lengthening, arthrodesis, tendon transpositions, resections)	14 (47)
Bilateral procedures, n (%)	6 (20)

2 Methods

2.1 Patients

Thirty-two children aged 6–16 years were consecutively included in the study after written informed consent was obtained. Baseline demographics, orthopaedic diagnoses and surgical procedures are listed in Table 1. The criteria for exclusion were cognitive impairments, severe coagulopathies or infection in the anatomical region of the PPT measurements. The study was approved by the Central Denmark Region Committee on Biomedical Research Ethics (M-20110140) and was carried out in accordance with the Declaration of Helsinki.

2.2 Pressure algometry

The pressure pain threshold (PPT) was assessed using a handheld algometer (Algometer®, Somedic Sales, Hörby, Sweden) with an application rate of 20 kPa/s as described by Nikolajsen et al. [1]. PPT is defined as the minimum pressure applied which induces pain and hence the children were instructed to say "stop" during the PPT assessment when the sensation of pressure changed to a sensation of pain. The applied pressure would subsequently be displayed on the algometer. All PPT assessments were conducted in a closed examination room with no external disturbances.

The PPTs were assessed as triple measurements in two anatomic locations. First, triple PPTs were assessed on the thenar of the dominant hand with the probe perpendicular to the first metacarpal bone. Second, triple assessments of PPTs were made on the lateral aspect of the lower leg, approximately 10 cm distally from the knee joint perpendicular to the fibula. In 9 cases of bilateral lower extremity surgery or regional block or epidural, the PPT assessment on the lower leg was omitted due to postoperative casting or anaesthesia. The PPTs used for statistical analysis was determined as an average of the last two assessments [1].

2.3 Procedure

All referred children requiring surgery were assessed for eligibility in the outpatient clinic 3–6 weeks before surgery at the department of Children's Orthopaedics at Aarhus University Hospital. If inclusion criteria were met, the child and parents were informed of the present study and subsequently the baseline PPT and Numerical Rating Scale (NRS) assessments were performed by one of the authors (LKP or PM). Prior to the PPT assessments the child was introduced to the pressure algometer and a test assessment was performed under non-stressful conditions to avoid any anxiety of the child. These assessments were repeated 1–2 h before surgery (Day 0) and before premedication was administered, the first postoperative day (Day 1) after pain medication and 6–12 weeks after surgery (Follow-up). All assessments of the individual child were performed by the same investigator. The timeline of the study is shown in Fig. 1.

2.4 Outcome measures

The primary outcome of the study was the difference of PPTs between baseline and day 1. The PPTs at baseline, day 0, day 1 and follow-up are also presented. In addition, the child's pain intensity was assessed at all four assessment times just prior to the PPT assessments using the Numerical Rating Scale (NRS), for which the instruction was, that zero is the absence of any pain and ten is the worst imaginable pain. Four patients received epidural analgesia, 24 patients were treated with regional nerve blocks and one patient received local infiltration analgesia. All patients were given NSAIDs, paracetamol and opioids as needed according to weight and analgesic use were subsequently assessed through medical records.

2.5 Statistical analysis

Data analysis was conducted using STATA version 11. Before the statistical analysis all continuous data were plotted to evaluate normal distribution. PPT data were not found to be normally distributed; hence a non-parametric statistical test was required. The Friedman test, similar to the parametric repeated measures ANOVA, was used to detect differences across multiple tests. Subsequently a *post hoc* analysis between the four different assessments was performed using the Wilcoxon signed rank test and results were adjusted for multiplicity using the Bonferroni test. Analysis of the correlations between PPT values, demographics, the NRS scores and the opioid consumption were carried out using the Spearman Correlation. Results are presented as median (range). A *p*-value of <0.025 after Bonferroni adjustment was considered to be significant.

A sample size calculation for the study was based on a continuous primary endpoint based on the population variance of the PPT value (183.1 kPa) and standard deviation (90.7) published by Nikolajsen et al. [1] with an expected difference between the PPT at baseline and at day 1 of 50 kPa. With 80% power and 95% significance level ($\alpha = 0.05$, $\beta = 0.2$) a sample size of 26 children in total was required.

3 Results

Two children only completed the baseline PPT assessment and their data were excluded, hence data from 30 children were used for analysis.

There was a statistically significant difference of PPTs during the four assessments ($\text{Friedman}_{crus} = 39.84$, $p = 0.000$; $\text{Friedman}_{thenar} = 78.56$; $p = 0.000$). *Post hoc* analysis with Wilcoxon signed-rank test was conducted with a Bonferroni adjustment resulting in a significance level set at $p < 0.025$.

The primary outcome defined as the change in PPTs between baseline and day 1 showed decreased PPTs on day 1 as hypothesized ($Z_{crus} = 2.373$, $p = 0.018$; $Z_{thenar} = 0.553$, $p = 0.581$). More surprisingly, a significant decrease in PPTs between baseline and day 0 was measured ($Z_{crus} = 2.475$, $p = 0.013$; $Z_{thenar} = 2.414$, $p = 0.016$). In other words, the PPTs showed a decrease between

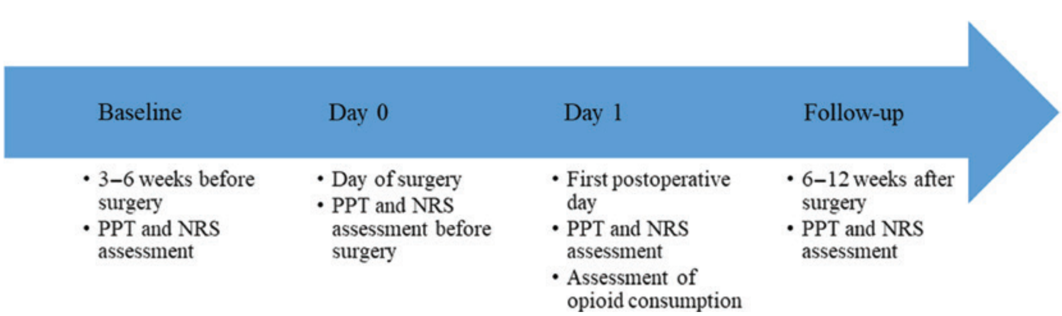

Fig. 1: Timeline of the study. All four assessment points are depicted.

baseline and day 0, a further decrease between day 0 and day 1 and finally an increase at follow-up. This development of the median PPTs at the four assessments are shown in Table 2. NRS showed a significant increase in the level of pain at day 1 ($p = 0.00$) and a return to baseline levels at follow-up ($p = 0.00$) (Table 2). The median opioid consumption during the first 24 postoperative hours corrected to body weight (opioid equivalent dosages per kg) was 0.17 mg/kg (range 0–1.9 mg/kg). PPTs were positively correlated to higher age ($p_{crus} = 0.017$; $p_{thenar} = 0.011$), weight ($p_{crus} = 0.011$; $p_{thenar} = 0.101$), and height ($p_{crus} = 0.009$; $p_{thenar} = 0.052$); but not to NRS ($p_{crus} = 0.270$; $p_{thenar} = 0.967$), or opioid equivalent use ($p_{crus} = 0.486$; $p_{thenar} = 0.700$).

The reproducibility of the PPT measurements was evaluated by a Coefficient of Variance (CoV), which is the ratio of the SD to the mean. A value below 10% is commonly considered to show good reproducibility. The mean CoV proved good reproducibility of the measurements (CoV_{crus}: 7.3%; CoV_{thenar}: 7.9%). The longitudinal within-subject variation of PPT was not assessed.

4 Discussion

The present study demonstrates that pressure pain thresholds (PPT) in children undergoing orthopaedic surgery significantly decreases from baseline to just prior to surgery and further decreases the first day postoperatively. We had hypothesized a postoperative decline of PPTs; however, the fact that a significant part of the decline of PPT was already present before any surgery was performed was surprising.

Table 2: PPT_{Crus} and PPT_{Thenar} and NRS (Range) at baseline, day 0, day 1 and follow-up.

	Baseline	Day 0	Day 1	Follow-up
PPT_{Crus}/kPa	248	171	146	235
Range	65–824	97–745	62–618	111–1124
25–75% IQR	171–311	137–293	130–256	176–439
n	20	20	19	18
PPT_{Thenar}/kPa	195	179	161	205
Range	100–591	67–554	63–604	78–648
25–75% IQR	166–281	123–241	122–261	145–350
n	29	29	28	27
NRS	1	0.7	3.6	0.4
Range	0–7	0–4	0–9	0–3
n	29	28	27	27

All PPTs are presented as median (Range). 25–75% IQR: 25% and 75% Inter Quartile Range for PPTs.

Several speculations may be made as to why the PPT declined in the period between the baseline and the day of surgery. This study hypothesized that the surgical trauma would influence PPTs, but since the decline of PPTs occurred before any surgical procedures were performed, other factors must have affected the PPTs. Palermo et al. [18] have investigated the predictors of children's postoperative pain and find that especially anticipatory anxiety is highly correlated to postoperative pain. In addition, it is underlined that anxiety may change over time and assessment of anticipatory anxiety at multiple time points may provide different results [18]. Goubert et al. [19] have shown that the children's level of anxiety, anticipation and pain catastrophizing thoughts of both the child and the parents might affect the threshold for perceived pain measured by algometry [19, 20]. This call for further studies regarding the effect of anticipatory anxiety, expected pain, catastrophizing, distraction, physical activity and genetics on pain modulation.

Other studies have tried to identify factors predictive of postoperative pain. Hsu et al. [8] have found that preoperative pain tolerance using pressure algometry is significantly correlated with the level of postoperative pain. Conversely, present study has not found any correlation between preoperative PPT and postoperative pain intensity. However, the primary aim of this study was to assess changes in PPTs rather than to measure pain intensity. In comparison, Uziel et al. [9] have studied the 5-year outcome of PPTs in a cohort of children with growing pain and have found that pain thresholds were similar but the children with continued growing pains had lower PPTs than healthy controls. Their study concludes that growing pain probably represents a pain amplifications syndrome of early childhood [7, 9]. This brings forth a discussion of which factors actually might influence the threshold for pain. One could argue that the psychological habitus of the child could be an overlooked factor in the development of both acute postoperative pain and chronic pain. In other words, since the threshold for pain in children seem to be largely affected by psychological factors it might be necessary to address this in the pain management. However, further studies are needed in order to identify both the target and intervention to reach a goal of better pain management in children.

This study may have some limitations. First, all children in this study needed orthopaedic surgery, and therefore might have had a preoperative painful condition affecting their tolerance and threshold for pain as well as their thoughts and expectations regarding pain. Second, the low patient number might limit this study although a valid power calculation was performed. Third, other studies have chosen different anatomic locations for the assessment of pressure algometry. For example, Chaves et al. [2] have obtained PPT assessments from 15 sites related to the temporomandibular region in children who reported orofacial pain. Soee et al. [13] have assessed PPTs at the dorsum of the second finger's interphalanx, m. temporalis and m trapezius in children with tension-type headache. Present study has assessed PPTs on the thenar and on the lateral aspect of the lower leg. Contrary to the exemplified studies, present study includes a range of different orthopaedic diagnoses; hence, the anatomic locations for the PPT assessments were more spread out anatomically including both the upper and lower extremities. This could, however, lessen the external validity of the study.

5 Conclusions

This study concludes that PPTs in children undergoing orthopaedic surgery significantly decrease from baseline to just prior to surgery, further decrease the first day postoperatively and returns to baseline values at follow-up. The decline of PPTs between baseline and just prior to surgery indicates that factors other than the surgical trauma modulate the threshold for pain and play a role in the perception of pain. Factors as for example anticipatory anxiety, psychological habitus, expected pain, catastrophizing, distraction, physical activity and patient education need to be studied further in relation to PPT and pain in children undergoing orthopaedic surgery. Awareness of pressure pain thresholds may help identify children with affected pain perception and hence improve future pain management in children undergoing orthopaedic surgery.

Authors' statements

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Informed consent: Informed consent has been obtained from all individuals included in this study.

Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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