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Original article

Evaluation of an oral analgesia protocol for upper-limb fracture reduction in the paediatric emergency department: Prospective study of 101 patients

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ABSTRACT

Background: Upper limb injuries are common in children. When required, closed fracture reduction can be performed in the emergency department without general anaesthesia but causes pain. The primary objective of this study was to assess an oral analgesia protocol for fracture reduction without general anaesthesia. The secondary objectives were to look for associations linking pain intensity to age, sex, and waiting time and to determine the frequency of secondary displacement requiring closed reduction or internal fixation under general anaesthesia at the 1-week follow-up visit.
Hypothesis: An oral analgesia protocol combining a loading dose of morphine with other medications would provide sufficient pain control to obviate the need for general anaesthesia.
Material and methods: A prospective observational single-centre study was conducted over a 15-month period (July 2017–October 2018) in consecutive patients younger than 16 years who required reduction of a displaced upper-limb fracture. All patients received the same oral combination of paracetamol (15 mg/kg), ibuprofen (7.5–10 mg/kg), and a loading morphine dose (0.5 mg/kg, up to 20 mg) 1 hour before the procedure. Patients given morphine more than 2 hours before the procedure and those with persistent pain were given an additional morphine dose (0.2 mg/kg, up to 10 mg). An equimolar mixture of oxygen and nitrous oxide was administered during reduction. An appropriate scale was used to measure pain intensity before, during, and 15 minutes after the procedure. Cases of secondary displacement requiring further reduction or internal fixation under general anaesthesia at the 1-week follow-up visit were recorded.
Results: The 101 study patients (73 male and 28 female) had a mean age of 9.4 years (range, 2-15 years). Mean pain scores were 5.0 ± 2.6 at admission and 2.1 ± 2.3, 2.6 ± 3.3, and 1.3 ± 2.2 before, during, and after reduction, respectively. Pain intensity during reduction was significantly associated with age. The analgesia was deemed satisfactory by 94 patients and 90 parents. General anaesthesia for further treatment was required in 10 (9.9%) patients, either on the day after the initial treatment, due to inadequate reduction ($n = 8$), or at the 1-week visit, due to secondary displacement ($n = 2$).
Discussion: Oral morphine in a sufficient dosage given in combination with other medications was effective and well tolerated when used to control pain during upper-limb fracture reduction. Pain intensity was not significantly associated with sex. In contrast, pain was significantly more severe in the patients older than 10 years of age. The proportions of patients requiring further reduction or internal fixation were consistent with previously published data. Most patients and parents were satisfied with the analgesia protocol.
Conclusion: A multimodal oral analgesia protocol provides sufficient pain relief to allow closed reduction of upper-limb fractures in children at the emergency department. This management strategy provided high satisfaction rates in both the patients and their parents.
Level of evidence: II, prospective observational study.

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1. Introduction

Accidents that happen in the course of daily activities cause many injuries in children and adolescents, of which 30% involve the upper limb. Among upper limb injuries, three in ten are forearm and wrist fractures [1–4]. Displaced fractures require closed reduction, which can be performed at the emergency department without general anaesthesia. However, closed reduction causes pain [5,6]. The recommendations issued by scientific societies about controlling moderate-to-severe pain due to injuries in children do not include clear guidelines about managing acute pain caused by manipulation of an injured limb [7,8]. Fentanyl and ketamine have been found effective in managing pain due to fracture reduction but are rarely used in emergency departments in France [9,10]. Oral morphine combined with ibuprofen is recommended for the management of severe pain due to injuries. However, no analgesia protocol has been validated for pain control during fracture reduction [11–13].

The primary objective of this study was to assess an oral analgesia protocol for fracture reduction without general anaesthesia. The secondary objectives were to look for associations linking pain intensity to age, sex, and waiting time and to determine the frequency of secondary displacement requiring closed reduction or internal fixation under general anaesthesia at the 1-week follow-up visit. Our working hypothesis was that an oral analgesia protocol combining a loading dose of morphine with other medications would provide sufficient pain control to obviate the need for general anaesthesia.

2. Material and methods

A prospective observational single-centre study was conducted over a 15-month period (July 2017–October 2018) in consecutive patients aged 1 to 16 years with displaced upper-limb fractures for which a paediatric orthopaedic surgeon advised closed reduction. Exclusion criteria were use of analgesics other than paracetamol, ibuprofen, and morphine; a contra-indication to any of these three drugs; intravenous analgesic therapy; need for surgical fracture treatment; multiple injuries; and poor patient comprehension compromising study feasibility. Oral informed consent was obtained from the parents and from patients older than 6 years of age. The study was approved by the institutional review board of the Rennes university hospital (#18.39).

2.1. Analgesia protocol

The analgesia protocol combined paracetamol 15 mg/kg (up to 1 g), ibuprofen 7.5–10 mg/kg (up to 400 mg), and oral morphine sulphate (Oramorph®) 0.5 mg/kg (up to 20 mg). These medications were given 1 hour before the estimated start of the reduction procedure. If reduction was finally performed more than 2 hours after drug intake or the pain intensity score on a visual analogue scale (VAS) was above 3/10, an additional morphine sulphate (Oramorph®) dose of 0.2 mg/kg (up to 10 mg) was given. An equimolar mixture of oxygen and nitrous oxide (EMONO) was started 3–5 minutes before starting the reduction and continued throughout the procedure, which was performed by an orthopaedic surgery resident. The emergency-department healthcare provider who attended the procedure assessed pain intensity just before, during, and 15 minutes after the reduction. Pain was assessed using an age-appropriate scale. Immobilisation was with a plaster cast. A radiograph was then obtained (Fig. 1).

2.2. Assessment methods and criteria

The patient and the parent who remained present during the reduction completed questionnaires to assess the effectiveness of the analgesia protocol. The following pain scales were used: visual analogue scale (VAS), numerical scale (NS), and EVENDOL scale or Face-Legs-Activity-Cry-Consolability (FLACC) scale. Preference was consistently given to self-evaluation.

The treatment target was a pain score $\leq$3/10 after analgesic administration, which was considered satisfactory for starting the procedure. Pain scores were assessed separately in two age

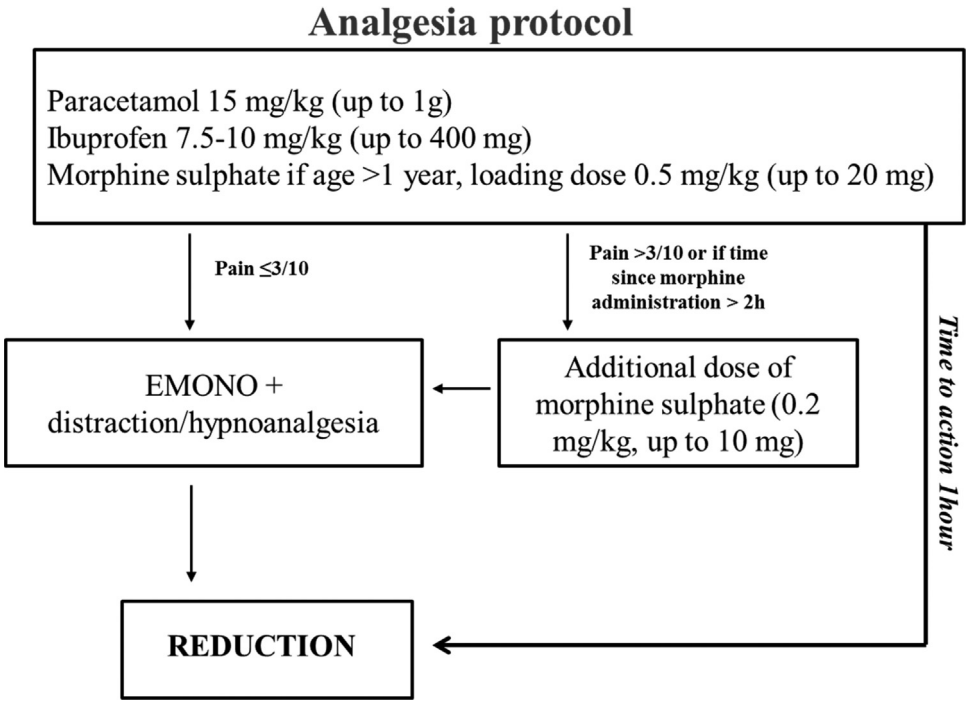

Fig. 1. Analgesia protocol used in the study.

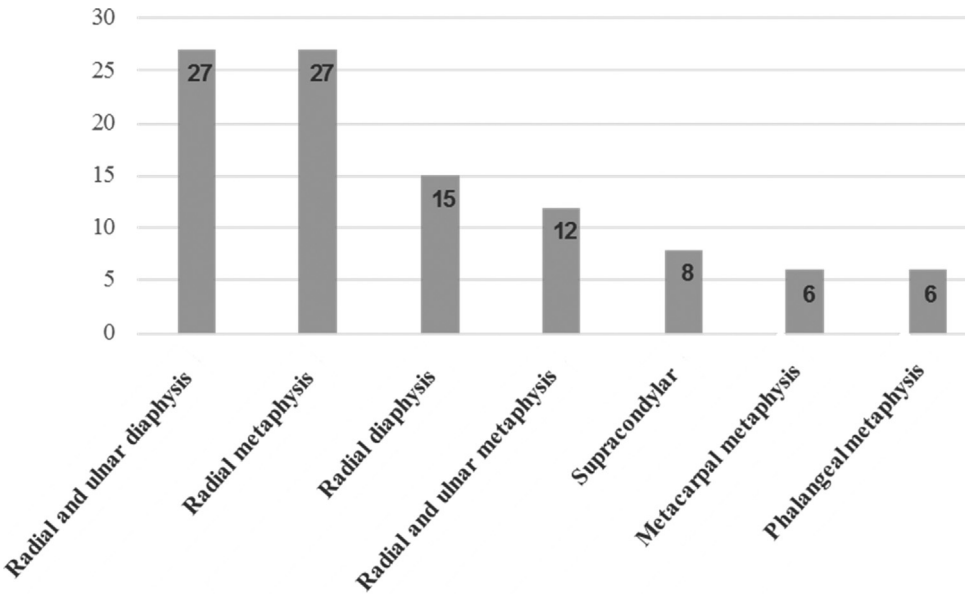

Fig. 2. Classification of the fracture types in the study population.

groups, ≤ 10 years and > 10 years of age. The time from emergency department arrival to reduction was recorded. The reduction was considered satisfactory if the radiographs obtained immediately after the procedure then 7 days later showed no abnormalities requiring treatment in the operating room. At the end of the procedure, the pain experience was assessed by asking the patient and parent, separately, whether they would agree to receive the same treatment again under the same conditions.

Nausea and vomiting were recorded as markers of gastrointestinal tolerance. A sedation score was determined to evaluate discharge readiness.

2.3. Statistical analysis

SPSS software (IBM, Armonk, NY, USA) was used for the statistical tests. Normally distributed data were described as mean ± SD and compared using Student's *t*-test. The only variable with non-normally distributed values was time to reduction, which was described as the median [interquartile range] Values of p smaller than 0.05 were taken to indicate significant differences. Pearson's or Spearman's correlation coefficients were computed to identify factors associated with pain intensity, among the following: age, sex, time from arrival to reduction, and pain intensity at arrival.

3. Results

The study included 101 patients, 73 males and 28 females, with a mean age of 9.4 years (range, 2–15 years). Each patient had unilateral upper limb involvement, yielding a total of 101 reduction procedures. Fig. 2 shows the fracture sites. Displacement was generally between 16° and 30° (Fig. 3). Mean pain intensity scores were as follows: at arrival, 5.0 ± 2.6; just before reduction, 2.1 ± 2.3; during reduction, 2.6 ± 3.3; and after reduction, 1.3 ± 2.2.

Compared to diaphyseal fractures, metaphyseal fractures were associated with significantly greater pain intensity, both in the overall study population and in the two age groups (> 10 years, 5.3 ± 2.4; ≤ 10 years, 4.8 ± 2.6; $p = 0.043$). The degree of fracture displacement was not associated with pain intensity ($p > 0.05$).

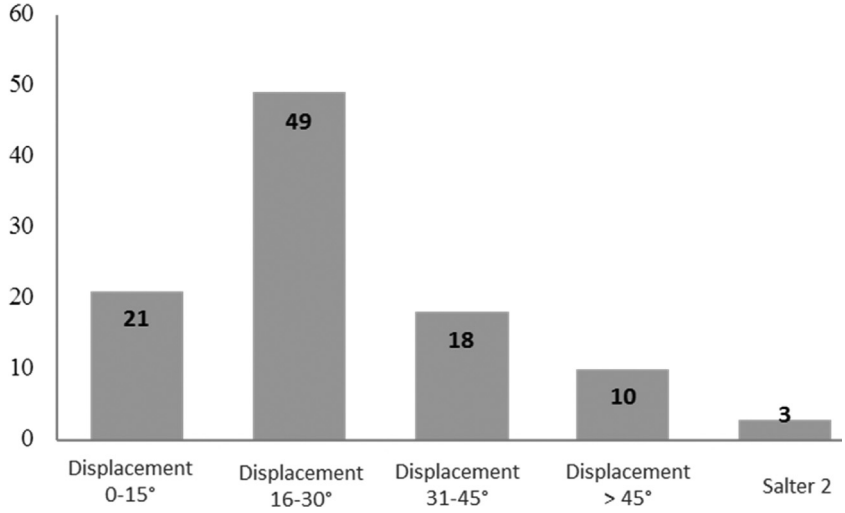

Fig. 3. Classification of fracture displacements in the study population.

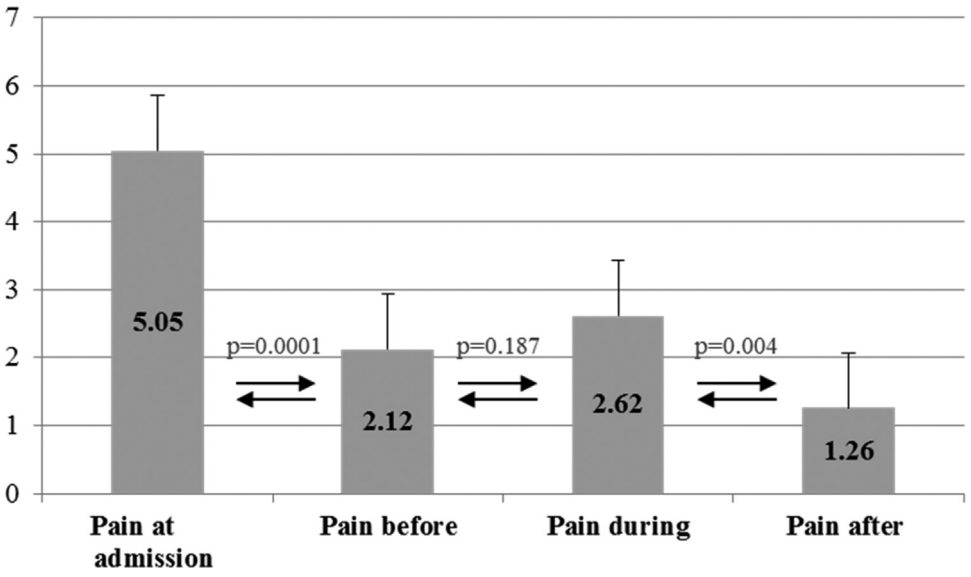

Fig. 4. Differences in pain intensity at admission and before, during, and after the procedure in the overall population.

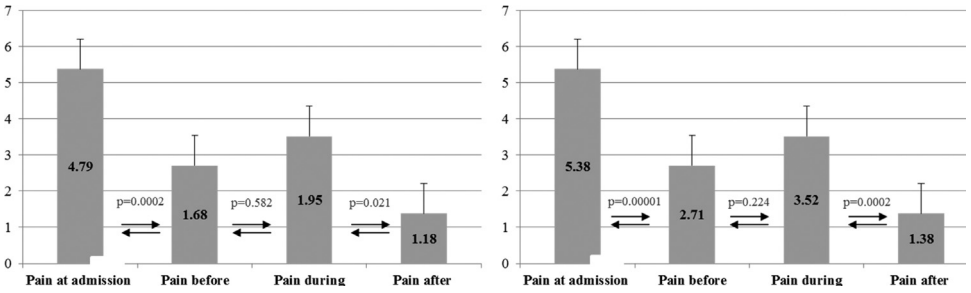

Fig. 5. Differences in pain intensity at admission and before, during, and after the procedure according to age.

An additional morphine dose was required before reduction in 12 (11.9%) patients. A statistically significant difference was found between the pain intensities at arrival and just before reduction ($p = 0.0001$, Student's t test). Statistically significant differences in pain intensity were also found between pain before and after reduction ($p = 0.0001$) and between pain during and after reduction ($p = 0.0002$) (Fig. 4).

Pain intensity was significantly greater in the group of patients > 10 years of age ($n = 43$) than in the younger group ($n = 58$) (5.4 ± 1.7 vs. 4.8 ± 2.8; $p = 0.025$) (Fig. 5). During reduction, mean pain intensity was also significantly greater in the older group (3.5 ± 3.6 vs. 1.9 ± 2.8, $p = 0.0004$) (Fig. 5) (Table 1).

Correlation coefficients were computed to look for links between pain intensity and age, sex, and time to reduction. Pain intensities at arrival and before, during, and after reduction were not different between males and females. In contrast, age correlated significantly with pain intensity at arrival ($p = 0.028$, $r = 0.227$), before reduction ($p = 0.002$, $r = 0.301$), and during reduction ($p = 0.004$, $r = 0.286$).

Median time to reduction was 3 hours [2-3.45]. Time to reduction was not significantly associated with pain intensity before, during, or after reduction ($p > 0.05$).

Nausea was reported by 7 (6.9%) patients and vomiting occurred in 2 (1.9%) patients.

Of the 101 patients, 94 (93%) said they would agree to receive the same treatment under the same conditions if required. Of the 101 parents, 90 (89%) shared this opinion. In all patients, the sedation score at discharge was S0, indicating recovery of normal alertness.

In 8 patients, treatment in the operating room on the following day was deemed necessary, due to inadequate reduction. Internal fixation was performed in 3 and further reduction in 5 of these patients. Secondary displacement required further reduction on day 8 in 2 patients (Table 2).

4. Discussion

This study demonstrated that combining pre-procedural oral morphine, paracetamol, and ibuprofen with EMONO during the

Table 1
Differences in pain intensity at admission and before, during, and after the procedure according to age.

Pain intensity(10-point scale)	Population ≤ 10 years	Population > 10 years	p-value
At admission	4.79 ± 2.82	5.38 ± 1.75	0.025
Just before reduction	1.68 ± 2.30	2.71 ± 2.23	0.974
During reduction	1.95 ± 2.84	3.52 ± 3.59	0.004
15 min after reduction	1.85 ± 2.31	1.38 ± 1.97	0.686

Table 2
Characteristics of fractures with insufficient reduction requiring surgery.

	Fracture type, location and displacement
1	Phalangeal metaphysis 0–15° displacement
1	Phalangeal epiphysis
1	Metacarpal epiphysis, Salter 2
1	Humeral metaphysis, displacement 0–15°
1	Humeral metaphysis/epiphysis, displacement 31–45°
1	Radial and ulnar metaphyses, displacement entre 16–30°
1	Radial diaphysis, displacement 16–30°
1	Radial diaphysis, displacement 0–15°
1	Radial metaphysis, displacement 3–45°
1	Radial metaphysis, displacement > 45°

procedure was effective in controlling pain during the reduction of upper-limb fractures in children. Importantly, the reduction procedure was started only after obtaining pain alleviation and allowing sufficient time for the oral analgesics to take effect. These findings confirm our working hypothesis.

The epidemiological characteristics of our population are consistent with earlier data. Pain intensity was not greater during than before the procedure [1–4]. An advantage of the protocol is that it does not require the placement of an intravenous line, which is unnecessary for the reduction and causes pain and anxiety. We chose morphine as a drug that is widely used at emergency-room arrival of patients with severe or very severe pain. Morphine was given either upon arrival or after the treatment decision was made, to prevent procedural pain. The protocol uses a single opioid and does not carry the risk of deep sedation seen when opioids are combined with anxiolytic agents [7]. A single morphine dose was sufficient in 87.5% of patients, probably due to the use of a loading dose (0.5 mg/kg), as recommended for severe pain in trauma patients [11]. Use of the maximum morphine dosage may be crucial to achieving sufficient pain control. In a recent randomised controlled trial, a morphine and ibuprofen combination was insufficiently effective in children, probably due to the morphine dosage of only 0.2 mg/kg, which we feel is too low in this situation [14].

The morphine was well tolerated, with no patient exhibiting signs of sedation that delayed discharge and only 9 having gastrointestinal symptoms. All the drugs in the protocol were regularly used in our department, allowing earlier and safer administration. Other agents suggested for pain relief during fracture reduction include propofol and intra-nasal fentanyl and ketamine [9,10,15]. Intra-nasal fentanyl combined with nitrous oxide seems to provide faster pain relief with a good safety profile. However, the study by Hoeffe et al. of fentanyl and nitrous oxide did not show lower pain scores compared to those in our study [9]. At present, these agents are not licensed for use for fracture reduction.

4.1. Other determinants of pain intensity

Interindividual variations in pain intensity were found, and pain scores differed significantly according to age, with worse pain at arrival and during reduction in the group older than 10 years. Emotional factors and the greater ability of older children to anticipate pain during treatment may explain this difference [12,16]. Thus, the absence of a significant post-procedural pain score difference between the two age groups supports the hypothesis that emotional factors played a substantial role in the pain experience during the reduction. Another factor may be the greater bone plasticity in younger children. The low pain scores after the procedure may be related to the fracture reduction and immobilisation, as well as to relief at knowing that the treatment was over. At none of the time points were the pain scores different between males and females.

4.2. Time to reduction

After arrival at the emergency department, time was needed for installation, evaluation, the diagnostic workup, information of the patient and parent, and arrival of an orthopaedic surgery resident before the reduction could be performed. The mean time from arrival to reduction was 2.9 hours. This time did not correlate with the pain scores. Milner et al. [17] reported that having the fracture reduced by an orthopaedic surgery resident seemed associated with greater stability but increased the time spent in the emergency department. Other studies have established that fracture reduction can be performed by specially trained emergency physicians, with the result being a shorter time from patient arrival to reduction [18,19].

4.3. Delayed treatments under general anaesthesia

In all, 10 (9.9%) patients had persistent fracture instability after reduction requiring delayed surgical treatment. Wendling et al. reported that, although closed reduction followed by immobilisation remained the treatment of choice in children with displaced radial fractures, surgical treatment was required subsequently in 14.4% of patients [20]. In a study by Pesenti et al. of outcomes of diaphyseal forearm fractures managed by reduction in the emergency department, only 1 (0.6%) of the 60 children had secondary displacement on day 8 and 5 (8.3%) others on day 15, inviting the conclusion that delayed surgical therapy is rarely needed in paediatric patients [6].

4.4. Satisfaction of the patients and parents

The high level of satisfaction of the patients and parents present during the procedure confirms the data reported by Betham et al. [21].

4.5. Study strengths and limitations

The strong points of this study include the prospective design and large number of patients, all of whom were re-evaluated on day 7. The non-randomised non-controlled design is a limitation. Performance of the reduction by an orthopaedic surgery resident after confirmation of the indication by a senior orthopaedic surgeon may have influenced the number of patients who required delayed treatment under general anaesthesia.

5. Conclusion

The oral administration of paracetamol, ibuprofen, and morphine at least 1 hour before the procedure, combined with EMONO during the procedure, provided effective pain control during the reduction and was well tolerated. This multimodal anaesthesia protocol decreased the time spent in the hospital and the number of patients requiring general anaesthesia. Randomised controlled trials would be of interest to compare the benefits of oral morphine and intra-nasal fentanyl.

Disclosure of interest

The authors declare that they have no competing interest.

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None.

Contributions of each author

V Chasle and P Violas supervised the research project and wrote the manuscript.

All other authors are paediatric emergency physicians and revised the manuscript for important intellectual content.

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