Original Article

Remodeling of distal radius fractures in children: preliminary retrospective cost/analysis in level II pediatric trauma center

Mario Marinelli[1], Daniele Massetti[2], Giulia Facco[3], Danya Falcioni[1], Valentino Coppa[1], Valentina Maestri[1] and Antonio Gigante[3]

[1]Clinic of Adult and Paediatric Orthopaedics, Ospedali Riuniti, Ancona, Italy; [2]Department of Orthopedic and Trauma Surgery, Ospedali Riuniti, Ancona, Italy; [3]Department of Clinical and Molecular Sciences, Università Politecnica delle Marche, Ancona, Italy.

Abstract. *Background and aim:* Children displaced distal radius fractures (DRFs) are commonly treated by reduction. Yet, their excellent remodeling ability provides good clinical-radiographic outcomes even in case of non-anatomical reduction. The reduction under analgesia or sedation involves hospitalizations, greater risks, and higher hospital costs. The aim of this preliminary study is to demonstrate the accountability and conveniency of non-anatomical reduction. *Methods:* The study involved all 0-8 years-old children who were affected by a closed overriding DRF from February 2017 to December 2018 and were managed non-operatively by a long arm cast without reduction, analgesia, or sedation treatments. We retrospectively evaluated their clinical-radiographic outcomes and healing time. The costs of no-reduction treatments were compared with those of the two main approaches to DRFs, that is: closed reduction under sedation and application of a long arm cast; closed reduction under anesthesia, percutaneous pinning, and application of a long arm cast. The comparison was based on the Diagnosis Related Group system. *Results:* We treated 11 children with an average initial radial shortening of 5±3 mm and average initial sagittal and coronal angulations of 4.0° and 3.5°, respectively. Average casting duration was 40 days. All patients achieved a full range of wrist motion without deformities. The procedure was respectively 7 times less expensive than closed reduction in emergency room under sedation and application of a long arm cast, and 64 times less expensive than closed reduction in the operating room under anesthesia, percutaneous pinning, and application of a long arm cast. *Conclusions*: In children aged 0-8 years, non-operative treatment of closed overriding DRFs with a long arm cast without reduction is a simple and cost-effective procedure with both clinical and radiographic medium-term excellent outcomes. (www.actabiomedica.it)

Keys words: distal radius fracture, overriding fracture, conservative treatment, remodeling, cost analysis

Introduction

Distal radial fractures (DRFs) account for 35-45% of all pediatric long bone fractures. For this reason, they most frequently require treatments in pediatric Emergency Departments (1, 2). DRFS' features vary in relation to force energy and direction applied to the wrist at the time of the trauma, giving rise to different types of fractures, such as incomplete ("torus", "buckle", "greenstick") or complete ("non-displaced" or "displaced") ones. Pediatric incomplete and non-displaced fractures of the radial distal metaphysis have an excellent healing and remodeling ability, providing satisfactory clinical and radiographic outcomes even in case of non-anatomical reduction (3, 4). Instead, there is no consensus about the best treatment of complete displaced DRFs (5), which appears more complicated and may lead to malpractice claims (6).

Reduction of complete displaced DRFs may not work even under anesthesia, especially in case of overriding fracture with radial shortening. Moreover, even after a successful reduction (2) these fractures may displace in the plaster cast, thus requiring further treatments. These procedures often raise the number of operations under analgesia / anesthesia, follow-up visits, X-ray exposures, patient discomforts and risks, and hospital costs (7). Several studies show that overriding DRFs children (with 15° angulation and 1 cm shortening) can heal and achieve complete remodeling without clinical or functional sequelae: these patients may thus return to normal levels activity without restrictions, pain, or stiffness (8, 9, 10). Even though these fractures are commonly reduced, literature findings suggest that reduction is not necessary in patients aged 0-8 years. Overriding DRFs managed with a long arm cast in 90° of elbow flexion without reduction have been reported to heal completely (11, 12).

Considering that fund allocation decisions aimed at the best possible clinical outcomes are based on cost-effectiveness analysis (13, 14), non-reduction conservative treatments of DRFs in a long arm cast can be a simple, time-saving, and cost-effective office procedure (1, 11, 12). This preliminary study examined the clinical and radiographic outcomes and healing time of fractures treated by this method and compares its cost to the two most common approaches to displaced DRFs based on Diagnosis Related Groups (DRGs). Despite all the evidence above, there are still many Authors that report complete displaced DRFs cases treated by closed or open reduction. The aim of this preliminary study is to validate a therapeutic algorithm for the conservative treatments of closed overriding DRFs in children aged up to 8 years, based on cost analysis.

Materials and methods

After the approval of this retrospective study by the local Ethics Committee, the database of the Level II Trauma Center of "Salesi" Children's Hospital (Ancona, Italy) was mined for records of 0–8 years-old patients who were presented to the Emergency Department (ED) with an overriding DRF (with or without fracture of the ulna) between February 2017 and December 2018. We excluded patients with known bone diseases, Salter-Harris type III and IV DRF, fractures in the site of a previous fracture, stress fractures, open fractures, fractures with neurovascular complications, and/or pathological fractures. An overriding position was defined as 100% dorsal translation and shortening of the distal radial segment. Parents or legal guardians gave informed consent to the use of children medical data for the study.

The conservative treatment consisted in immobilization in a long arm cast in 90° of elbow flexion without reduction. The cast was gently molded to reach the correct angulation. The long arm cast was preferred to the short one because the former can be easily removed by children, thus not requiring a further admission to the hospital. The procedure was performed in the office without analgesia or sedation. An X-ray was taken after casting. Patients returned for clinical and radiographic follow-up after 1, 4 or 6 weeks (depending on age), and 1 year later. The cast was removed based on radiographic evidence of good callus formation. Sagittal and coronal angulation was measured on X-rays after casting and at a year follow-up. Records were examined for deformity, wrist range of motion, muscle strength, and tenderness in the fracture site.

This treatment and the other two most common approaches to pediatric closed displaced DRFs evaluation was grounded on clinical and radiographic outcomes, fracture healing time, and total average cost in 2018 for our region (Marche). Cost analysis were based on the ICD 9 CM classification and the DRG systems.

The most common approaches included:

1. clinical evaluation with immobilization in a long arm cast without fracture reduction, final X-rays.

As well as the common reduction procedures below:

2. closed reduction in the emergency room under conscious sedation, application of a long arm cast, final X-rays
3. closed reduction in the operating room under anesthesia, percutaneous pinning, application of a long arm cast, final X-rays.

Statistical methods

Raw radiographic data were used to measure the mean and standard deviation (SD) of each category.

Results

Eleven children, 8 boys and 3 girls with an average age of 6.2 years (range, 3-7) and a follow-up duration of a year met the inclusion criteria. The right arm was involved in 4 patients and the left arm in 7 patients. There were 8 isolated DRFs and 3 DRFs associated to a complete fracture of the ulna. The mechanisms of injury included sport trauma (4 patients), roller-skating accidents (3 patients), bicycle accidents (2 patients), and falls from a height at home (2 patients). The mean duration of casting (± SD) was 40 ± 10 days (range, 28-60). All patients were treated in the office by immobilization in a long arm cast in 90° of elbow flexion with no attempt at reduction and without analgesia / sedation. The fracture parameters, measured on X-ray scans, are reported in Table 1.

Mean radial shortening immediately after casting was 5 ± 3 mm (range, 1-17 mm). Angulation was measured immediately after casting and at the final follow-up visit. Mean angulation immediately after casting was 4.0° ± 4.2° (range, 0-13°) in the sagittal plane and 3.5°± 3.2° (range, 0-10°) in the coronal plane; at the final follow-up it was respectively 2.2° ± 2.7° (range, 0-10°) and 0.9° ± 1.5° (range, 0-5°). At the final follow-up visit all patients had full range of wrist motion; none reported pain or tenderness at the fracture site or pain during wrist movement. There were no complications involving the growth plate, neurovascular injuries, or cases of deformity, nonunion or malunion. At the time of cast removal, 4 patients had minimal deformity (Fig. 1-6). All children returned to normal activities without restrictions.

The total cost of care with each approach was calculated on 17th April 2020 using the calculator on the website http://www.e-drg.it/drg/TipoRicerca.asp. The results were as follows:

1. clinical evaluation with immobilization in a long arm cast without fracture reduction (the treatment proposed in the present study), and final X-ray: €40
2. closed reduction in the emergency room under conscious sedation, immobilization in a long arm cast, and final X-ray: €276

Table 1: Radiographic measurements after cast application and at one year.

	Mean and standard deviation (°)	Range (°)
Initial radiographs		
Sagittal angulation	5.0 ± 4.0	0-12
Coronal angulation	13.0 ± 3.5	0-10
Final radiographs		
Sagittal angulation	2.0 ± 2.8	0-11
Coronal angulation	0.8 ± 1.4	0-6

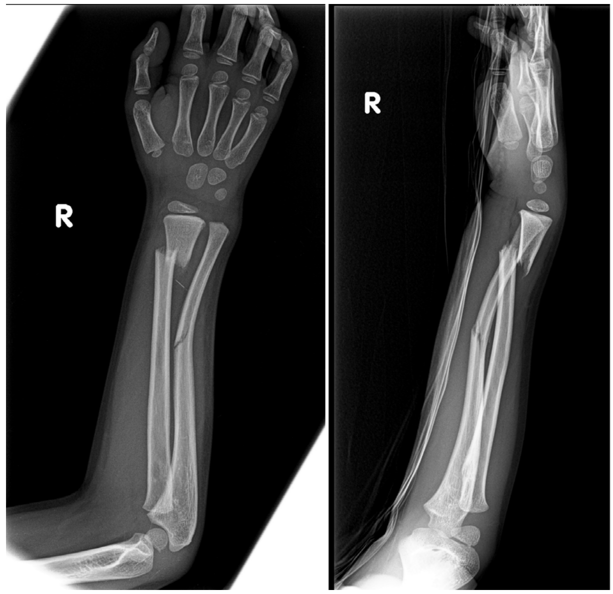

Figure 1. Anterior-posterior and lateral X-rays of an overriding distal radial fracture in a 5-year-old child.

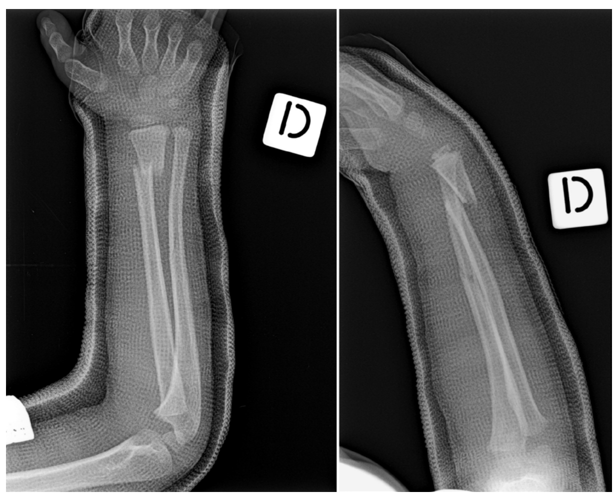

Figure 2. Same patient: anterior-posterior and lateral X-rays of an unreduced overriding distal radial fracture after the application of a long arm cast.

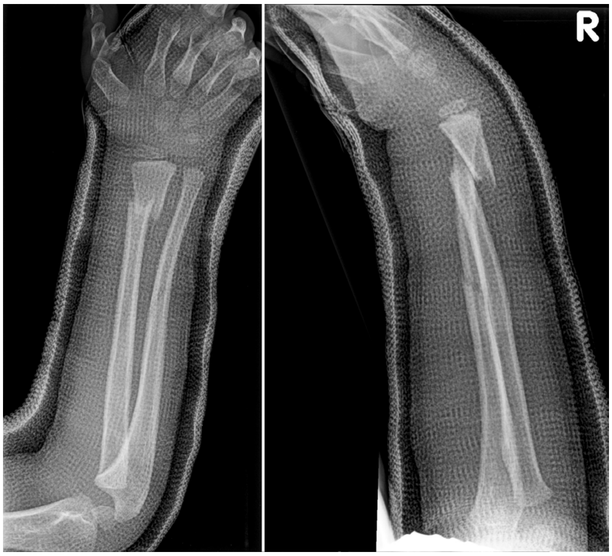

Figure 3. Same patient: anterior-posterior and lateral X-rays after 7 days in a long arm cast.

Figure 4. Same patient: anterior-posterior and lateral X-rays after 4 weeks in a long arm cast.

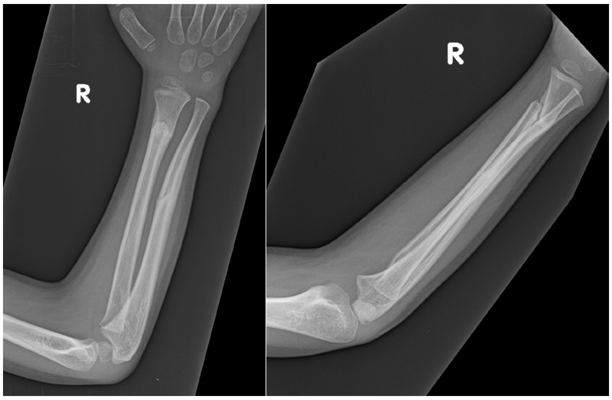

Figure 5. Same patient: anterior-posterior and lateral X-rays after 8 weeks in a long arm cast.

Figure 6. Same patient: anterior-posterior and lateral X-rays 6 months after the fracture.

3. closed reduction in the operating room under general anesthesia, percutaneous pinning, immobilization in a long arm cast, and final X-rays: €2550.

Immobilization in a long arm cast without reduction provided highly significant savings (Table II), since closed reduction under anesthesia and pin fixation in the operating room under anesthesia were, respectively, nearly 7 and 64 times more expensive.

Table 2. Treatment cost according to the DRG system of the Italian National health Service.

Treatment	Cost
Clinical evaluation with immobilization in a long arm cast without fracture reduction (the treatment proposed in this study) and final X-rays	**€40**
Closed reduction in the emergency room under conscious sedation, immobilization in a long arm cast and final X-rays	**€276**
Closed reduction in the operating room under general anesthesia, percutaneous pinning, immobilization in a long arm cast and final X-rays	**€2550**

Discussion

In patients aged up to 10 years, displaced distal fractures of the radial metaphysis have excellent remodeling ability and their clinical and radiographic medium-term outcomes (6-12 months) are satisfactory even in case of non-anatomical reduction (11). In particular, isolated DRFs with a dorsovolar or radioulnar angulation up to 15° and less than 1 cm shortening undergoes rapid healing and remodeling without significant clinical deformity or residual functional limitations, even in presence of major displacement, as in clavicular fractures (8, 9, 10). The distal radial and ulnar physes are responsible for 80% of forearm length and for 40% of upper limb length (15). In fractures close to the growth plate, the remodeling potential approaches 100% (16). Therefore, Children less than 10 years old show a high remodeling ability as well as a high potential to correct angular deformity. DRF patients in developmental age with at least 2 years of residual growth can achieve remodeling of up to 20° of angulation even in case of radial shortening (17). In a retrospective study of 34 children (mean age 9.2 years, range, 3–14) with DRFs that displaced in the cast after reduction, Do et al. reported excellent results with no residual clinical or functional deficit (1).

The approach proposed herein involved patients aged up to 8 years without sensitive or motor disorders or known metabolic disorders. Patients were affected by overriding DRFs, treated by immobilization in a long arm cast with the wrist in resting position (without reducing angulation or radial shortening). There are abundant data for the safety and effectiveness of this treatment (8-10); in addition, a more aggressive management does not yield better results either in terms of compliance or in terms of clinical outcomes (5). Yet, given the increasingly widespread malpractice claims (6), leaving the fracture to follow its natural course may pose problems. Therefore, when proposing the treatment, it is essential to explain the natural history of fracture healing and remodeling to the patient's family, also with the help of clinical and radiographic evidence.

An analysis of literature demonstrates that this office procedure is safe and effective and ensures patient outcomes close to those provided by the two approaches applied most frequently to treat these fractures (closed reduction in the emergency room under conscious sedation, and closed reduction in the operating room under general anesthesia and percutaneous pinning). Given the absence of conclusive evidence for any one of these approaches, we thought that a cost analysis using the DRG codes and the ICD 9 CM classification system (the latter, specific for the Marche Region, 2018) could assist in treatment choice.

The cost analysis of Italian National Health Service procedures is hampered by differences among regions criteria and by the lack of corrective measures enabling adaptation to pediatric procedures. A DRG is a patient classification system that standardizes health care refunds by the central government, usually covering all the charges related to outpatient treatments and inpatient stay from admission to discharge. DRGs have been devised to provide a fair mechanism ensuring best efficiency and encouraging cost containment. However, they are also key drivers of clinical behavior. The use of DRGs constitutes a way of describing clinical activities based on actual resources and it is also useful to compare different procedures costs.

Based on our cost analysis, the proposed procedure involves clinical examination, immobilization in a long arm cast with no attempt to reduce the fracture, and an X-ray scan after casting. Its cost according to the regional ICD 9 CM table is €40. The second approach, envisaging closed fracture reduction in the emergency room with the assistance of an anesthesiologist, followed by application of a long arm cast and an X-ray scan, involves two codes, #81344 for the diagnosis ("closed radius and ulna fracture") and #7902 for the treatment ("closed reduction without internal fixation"); their combination yields the DRG code #251, whose cost is €276 if the patient is discharged the same day (as in one-day surgery procedure), or €830 in case of an overnight stay (as in ordinary hospitalizations). The third approach, involving closed reduction and percutaneous pinning in the operating room under general anesthesia, immobilization in a long-arm cast, and an X-ray scan, includes #81344 code for the diagnosis of "closed radius and ulna fracture" and #7912 for "closed reduction with internal fixation"; their combination yields DRG #224, which corresponds to €2040 if the patient is discharged the same day, or €2550 if an overnight stay is required. Indeed, the cost analysis demonstrated that the procedure was also highly cost-effectives.

The chief limitations of this preliminary study, i.e. the lack of a control group and the small and heterogeneous patient sample, can be overcome by a prospective randomized controlled trial, maybe with a longer follow-up.

A recent systematic review (5) has found no conclusive data to determine the best treatment for wrist fractures in developmental age patients, even if many studies show that conservative treatment has a very good outcome in most of cases.

Conclusion

Based on the clinical evidence, we believe that the cost-effectiveness criterion can guide surgeons in their procedure choices, thus improving allocative efficiency and encouraging cost containment. The proposed treatment in this preliminary study requires neither close follow-up to check secondary displacement, nor the presence of an anesthesiologist; it can be routinely performed in the office by a small team to achieve outcomes similar to those of the approaches involving closed reduction with or without internal fixation. This treatment protocol can be considered as an effective alternative approach to pediatric overriding DFRs and provides the orthopedic surgeon with a simple, effective, cheap, and fast method.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

References

1. Do TT, Strub WM, Foad SL, Mehlman CT, Crawford AH. Reduction versus remodeling in pediatric distal forearm fractures: a preliminary cost analysis. J Pediatr Orthop B. 2003 Mar;12(2):109-15. doi: 10.1097/01.bpb.0000043725.21564.7b. PMID: 12584495.
2. Wendling-Keim DS, Wieser B, Dietz HG. Closed reduction and immobilization of displaced distal radial fractures. Method of choice for the treatment of children? Eur J Trauma Emerg Surg 2015;41:421–428. doi: 10.1007/s00068-014-0483-7
3. Aitken A.P. Further observations on the fractured distal radial epiphysis. J Bone Joint Surg 1935; 17:922–927.
4. Wilkins KE. Principles of fracture remodeling in children. Injury 2005; 36 (Suppl 1): A3-11. doi: 10.1016/j.injury.2004.12.007.
5. Handoll HH, Elliott J, Iheozor-Ejiofor Z, Hunter J, Karantana A. Interventions for treating wrist fractures in children. Cochrane Database Syst Rev. 2018 Dec 19;12:CD012470. doi: 10.1002/14651858.CD012470.pub2.
6. DeNoble PH, Marshall AC, Barron OA, Catalano LW 3rd, Glickel SZ. Malpractice in distal radius fracture management: an analysis of closed claims. J Hand Surg Am.2014 Aug;39(8):1480-8. doi: 10.1016/j.jhsa.2014.02.019. Epub 2014 Apr 29.
7. Pena B, Kraus B. Adverse events of procedural sedation and analgesia in a pediatric emergency department. Ann Emerg Med 1999; 34:483–491.
8. Price C, Scott D, Kurzner M, Flynn J. Malunited forearm fractures in children. J Pediatr Orthop 1990; 10:705–712.
9. Roy D. Completely displaced distal radius fractures with intact ulnas in children. Orthopedics 1989; 12:1089–1092.
10. Crawford AH. Pitfalls and complications of fractures of the distal radius and ulna in childhood. Hand Clinics 1988; 4:403–413.
11. Crawford SN, Lee LS, Izuka BH. Closed treatment of overriding distal radial fractures without reduction in children. J Bone Joint Surg Am. 2012 Feb 1;94(3):246-52. doi: 10.2106/JBJS.K.00163. PMID: 22298057.
12. Mark A. Seeley MD, Peter D. Fabricant MD, MPH, J. Todd R. Lawrence MD, PhD Teaching the Basics: Development and Validation of a Distal Radius Reduction and Casting Model Clin Orthop Relat Res 2017; 475:2298–2305. doi: 10.1007/s11999-017-5336-3
13. Marinelli M, Di Giulio A, Mancini M. Validation of the Ottawa Ankle Rules in a II level Trauma Center in Italy. J Orthopaed Traumatol 2007; 8(1): 16-20.
14. Marinelli M, Soccetti A, Panfoli N, de Palma L. Cost-Effectiveness of Total Hip Arthroplasty. A Markov Decision

Analysis based on implants cost. Journal of Orthopedics and Traumatology 2008; 9(1): 23-28.
15. Ogden JA, Beall JK, Conlogue GJ, Light TR. Radiology of postnatal skeletal development. IV. Distal radius and ulna. Skeletal Radiol. 1981;6:255-66.
16. Friberg KS. Remodelling after distal forearm fractures in children. III. Correction of residual angulation in fractures of the radius. Acta Orthop Scand. 1979;50(6 Pt 2):741-9.
17. Noonan KJ, Price CT. Forearm and distal radius fractures in children. J Am Acad Orthop Surg. 1998;6:146-56.

Correspondence:
Received: 30 June 2021
Accepted: 7 September 2021
Giulia Facco, MD
Department of Clinical and Molecular Sciences, Università Politecnica delle Marche,
Via Tronto 10/a, 60020 Torrette di Ancona – Italy.
Phone: +39.0712206066
Fax: +39.0712206203
E-mail: g.facco@pm.univpm.it