Journal of Orthopaedics 16 (2019) 31–35

Contents lists available at ScienceDirect

Journal of Orthopaedics

journal homepage: www.elsevier.com/locate/jor

Conservative versus surgical treatment of Gartland type 2 supracondylar humeral fractures: What can help us choosing?

Carlo Iorio[a,*], Marco Crostelli[a], Osvaldo Mazza[a], Pierpaolo Rota[b], Vincenzo Polito[b], Dario Perugia[b]

[a] Orthopaedics and Spine Surgery Unit, Bambino Gesù Pediatric Hospital, Rome, Italy
[b] Department of Orthopaedics and Traumatology, Sant'Andrea Hospital, University of Rome "La Sapienza", Rome, Italy

ARTICLE INFO

Keywords:
Pediatric supracondylar humeral fractures
Gartland type 2 treatment
Elbow fractures
Pediatric orthopaedics
Pediatric trauma

ABSTRACT

Background: Pediatric supracondylar humeral fractures (PSHF) are most common elbow fractures among children and adolescents. While there is substantial agreement on treating type 1 and type 3 fractures (conservatively and surgically, respectively), the debate on optimal treatment of Gartland type 2 fractures is still open.

We wanted to review our cases, analyzing outcomes and seeking for parameters that could help surgeons treating these injuries.

Methods: We retrospectively reviewed 41 patients treated with reduction and casting (group A) and matched to 38 patients treated with closed reduction and percutaneous pining (CRPP, group B) for Gartland type 2 fractures between 2009 and 2013. At a mean follow-up of more than 6 years patients were analyzed by an accurate clinical exam and evaluation scales. Radiographic parameters at time of cast or pins removal were studied too.

Results: There were no statistically significant differences in clinical exam and evaluation scales between groups. Two patients in group A developed a cubitus varus deformity and one patient in group B had a superficial pin-tract infection. Baumann angle (BA) was out of normal range in two cases of conservative group and anterior humeral line (AHL) bisected capitellum in 42.1% of patients in group A and 73.2% in group B ($p < .05$).

Conclusion: It is reasonable to expect satisfactory outcomes both after conservative and surgical treatment of type 2 fractures, if cornerstones of both treatments are applied. Parameters that should be focused are probably two: complications (2 cases of cubitus varus in group A versus one superficial pin-tract infections in group B) and the better trend in surgical group in regards to loss of flexion and hyperextension of the affected elbow, likely related to the other notable datum, that is the percentage of cases in which AHL bisects capitellum. We think that, in absence of vascolonervous lesions and important swelling, BA and AHL are the most important parameters that can help us choosing the optimal treatment, as clarified in the algorithm we developed.

Level of evidence: Level III – retrospective comparative study.

1. Introduction

Supracondylar humeral fractures are most common elbow fractures among children and adolescents, being about 85% of all elbow fractures.[1,2] Their incidence is about 177 cases per 100000 persons/year[1] and frequently affect children between 4 and 9 years of age.[1,3] In 97–98% of cases extension type fractures are observed[4] and a correlation between these injuries and the use of monkey bars and trampolines has been recently described.[5,6]

Gartland classification divides extension fractures in type 1 (no displacement), type 2 (posterior displacement of the distal fragment without posterior hinge disruption) and type 3 (complete displacement).[7] Then Wilkins modified this classification dividing type 2 fractures in 2A (posterior displacement only) and 2B (displacement plus translation/rotation of the distal fragment).[1]

While treatment of type 1 and type 3 fractures has substantial agreement among orthopedic surgeons (conservative and surgical approach, respectively), the debate on optimal treatment of Gartland type 2 injuries is still open. Some authors advocate closed reduction and percutaneous pinning (CRPP) of these fractures in order to better maintain reduction, avoiding consolidation defects and subsequent deformities,[8–10] and stating that the risk of developing decreased range

* Corresponding author. Orthopaedics and Spine Surgery Unit, Bambino Gesù Pediatric Hospital, Piazza Sant'Onofrio, 4, 00165, Rome, Italy.
E-mail address: carlo.iorio@opbg.net (C. Iorio).

https://doi.org/10.1016/j.jor.2018.12.001
Received 3 October 2018; Accepted 2 December 2018
Available online 18 December 2018

of motion (ROM) and compartment syndrome is higher following conservative treatment[11,12]; other colleagues prefer reduction and casting because they lead to satisfying clinical and radiologic results without exposing patients to anesthetic and surgical risks.[11,13] It has furthermore been reported how operating on all type 2 fractures could result in more than 70% of unnecessary surgery, suggesting that conservative treatment should be adopted at least as first line of therapy.[13]

Wilkins modification has been often used to try to solve this dilemma, addressing type 2A to casting and type 2B to surgery; but many doubts about the validity of this distinction have emerged, and several authors report low rates of intra- and inter-observer agreement in distinguishing 2A and 2B[14,15]; moreover, in Appropriate Use Criteria (AUC) published by American Academy of Orthopaedic Surgeons (AAOS) in 2015,[16] there is no mention of this distinction.

In this paper we want to report our experience in treating type 2 pediatric supracondylar humeral fractures (PSHF), comparing conservative versus surgical treatment, and eventually seeking for clinical and radiological parameters that could help us choosing the best option for our patients.

2. Materials and methods

We retrospectively reviewed 41 children conservatively treated (reduction and plaster casting at 90–110° of flexion) for a Gartland type 2 PSHF at a large tertiary children's hospital between January 2009 and December 2013 (Group A) and matched with 38 patients surgically treated (2 or 3 lateral-entry divergent pins) with CRPP for the same injury during the same period at an academic tertiary hospital, Italy (Group B). Exclusion criteria were Gartland type 1 and 3 extension-type fractures, flexion-type fractures, open fractures and age under 3 or over 12 years.

Clinical evaluation included ROM measurement (extension, flexion, total arc of movement, pronation and supination) with a goniometer of both injured and unaffected arm; hyperextension was indicated with positive values, while negative values were used for lack of extension recovery.[17] Then patients underwent evaluation scales such as the Quick Disabilities of the Arm, Shoulder and Elbow (QuickDASH) and the Mayo Elbow Performance Score (MEPS), and results were furthermore classified according to Flynn criteria, assessing range of motion and clinical carrying angle.[18]

After 5–7 days since cast application or CRPP patients have undergone radiological exams and X-rays at the moment of cast or pins removal (24 days, range 19–28 days for group A and 29 days, range 23–33 days for group B) have also been analyzed, measuring Baumann angle (BA, normal values between 64° and 81°; Fig. 1)[19] and observing the anterior humeral line (AHL), which should bisect the capitellum in sagittal view[20,21] (Fig. 2).

Student's *t*-test and x^2 have been used, and statistically significant level has been set at 5% ($p < .05$).

3. Results

Mean age was 6.4 years (range 4–11 years) in group A and 5.2 years (range 3–11 years) in group B; in group A there were 17 (44.3%) males ant 21 (55.7%) females and the dominant arm was affected in 10 (27.6%) of cases. In group B there were 21 (52.4%) boys and 20 (47.6%) girls and dominant arm was injured in 15 (36.6%) patients (Table 1).

Mean follow-up was 78 months (range 67–96 months) in conservative group and 75 months (range 64–100 months) in surgical group. There were no lesions of vascular and nervous structures and no compartment syndromes in both groups. In group B there was a pin tract infection, successfully treated with oral antibiotic therapy (Table 1).

At follow-up, mean elbow extension value in group A was 14.2° (range 0°–23°), mean flexion of 136.6° (range 125°–150°) and a mean total arch of movement of 150.1° (range 146°–160°); mean results in surgical group were 11.4° (−5°–15°) of extension, 139.3° (range 130°–150°) of flexion and 151.7° (range 135°–160°) of total ROM. Pronation and supination were 88.8° (range 80°–90°) and 89.4° (range 85°–90°) in group A and 89.3° (range 85°–90°) and 89.8° (range 85°–90°) in group B, respectively (Table 1).

QuickDASH mean scores were 2.2 (range 0–11.4) in conservative group and 1.9 (range 0–9.1) in CRPP group, while MEPS mean results were excellent in 100% of patients in both groups (Table 1).

Functional Flynn criteria (ROM) were excellent in 18 (47.4%), good in 13 (34.2%), fair in 2 (5.3%) and poor in 5 (13.1%) patients in group A and excellent in 20 (48.8%), good in 15 (36.6%), fair in 4 (9.7%) and

Fig. 1. X-ray in A-P view showing physiologic Baumann Angle.

Fig. 2. Elbow X-ray in lateral view. Note the anterior humeral line correctly bisecting the capitellum.

Table 1
Demographic data and major outcomes of the work (* = $p < .05$).

	Group A	Group B
Age	6.4 years (4–11 years)	5.2 years (3–11 years)
Males/Females	44.3%/55.7%	52.4%/47.6%
Dominant/Non Dominant	27.6%/72.4%	36.6%/63.4%
Clinical Follow-Up	78 months (67–96 months)	75 months (64–100 months)
Radiological Follow-Up	24 days (19–28 days)	29 days (23–33days)
Neurovascular Lesions	0	0
Compartment Syndromes	0	0
Infections	0	1 (superficial pin-tract)
Cubitus Varus	2	0
Hyperextension	14.2° (0°–23°)	11.4° (-5–15°)
Flexion	136° (125°–150°)	139.3° (130°–150°)
Total ROM	150.1° (146°–160°)	151.7° (135°–160°)
Pronation	88.8° (80°–90°)	89.3° (85°–90°)
Supination	89.4° (85°–90°)	89.8° (85°–90°)
QuickDASH	2.2 (0–11.4)	1.9 (0–9.1)
MEPS	100% Excellent	100% Excellent
Functional Flynn (ROM)	Excellent 47.4%; Good 34.2%; Fair 5.3%; Poor 13.1%	Excellent 48.8%; Good 36.6%; Fair 9.7%; Poor 4.9%
Estetic Flynn (Clinical Carrying Angle)	Excellent 63.1%; Good 21.1%; Fair 10.5%; Poor 5.3%	Excellent 80.5%; Good 17.1%; Fair 2.4%; Poor 0%
Clinical Carrying Angle	6.7° (−20°–18°)	9.7° (5°–16°)
Baumann Angle	73.1° (68°–87°)	71.6° (70°–77°)
AHL Bisects Capitellum*	42.1%	73.2%

poor in 2 (4.9%) patients in group B; according to Flynn aesthetic criteria (carrying angle), results were scheduled as excellent in 24 (63.1%) cases, good in 8 (21.1%), fair in 4 (10.5%) and poor in 2 (5.3%), while in group B there were 33 (80.5%) excellent, 7 (17.1%) good, 1 (2.4%) fair and no (0%) poor outcomes. Two patients who reported poor results in group A developed a cubitus varus deformity. In particular, mean clinical carrying angle values were 6.7° (range −20°-18°) in group A and 9.7° (range 5°–16°) in group B (Table 1).

No clinical statistically significant values were arisen.

Radiological results showed an average Baumann angle of 73.1° (range 68°–87°) in group A and 71.6° (range 70°–77°) in group B ($p > .05$). In 2 cases BA was out of normal values range, and these were the patients who developed cubitus varus deformity, both included in nonsurgical group (Table 1).

Anterior humeral line bisected the capitellum in lateral view in 16 patients (42.1%) of conservative group and 30 (73.2%) patients belonging to surgical group ($p < .05$; Table 1).

4. Discussion

Gartland type 2 PSHF are between 10% and 25% of elbow fractures region.[3,22–24] Moraleda et al.[17] showed how natural history of this pathology (with no attempt of reduction) leads up to 36.9% of unsatisfying results according to authors' criteria, although the majority of patients doesn't complain about functional outcomes obtained (93.5% and 97.8% of satisfactory results at MEPS and QuickDASH, respectively); in particular, comparing to the unaffected arm, a comparable ROM has been detected, with only a mild flexion deficit and a slight hyperextension, and cubitus varus incidence was 26%.

A total rate of about 1% of complications has been reported after PSHF,[25] and these are: vascular and nervous lesions, compartment syndromes, infections, loss of reduction and angular deformities onset. The brachial artery is most frequently affected, as it can be damaged or remain trapped between fracture fragments in about 0.5% of cases,[26] while nervous lesions (especially to anterior interosseous nerve, but also to radial nerve and ulnar nerve) can occur up to 20% of patients; radial nerve lesions regress often spontaneously in 3–6 months,[20,27] while ulnar nerve can be damaged in case of a medially inserted pin[28,29].

Mapes et al.[30] described how, under Doppler control, radial pulse in PSHF disappears at a mean of 128° (range 120°–130°) of elbow flexion, discouraging immobilization to more than 120° of flexion, when nonsurgical treatment is pursued, in order to avoid potential risk of developing a compartment syndrome, whose onset is estimated between 0.1% and 0.3%.[20,31] Skaggs et al.[32] pointed out how in case of ecchymosis and severe swelling, even with a preserved radial pulse and a good capillary refill, attention must be paid to the possible appearance of compartment syndrome, especially if a median nerve lesion is associated to the fracture.[20] Bae et al.[33] reported however very good results when performing fasciotomy within 30.5 h from the injury.

An article published in 2013[34] highlighted how Gartland type 2 fractures that require reduction to obtain satisfactory alignment have up to 48% of chence of losing reduction without pinning. In case of treatment with CRPP, conversely, Pennock et al.[35] emphasized the importance of inter-pin distance in maintaining reduction, stating that it should be at least of 13 mm or equal to 1/3 of the humerus width at fracture site.

In our patient sample there were no vascular and nervous lesion, as well as no compartment syndrome and no loss of reduction. Probably, excluding type 3 fractures, immobilizing arms between 95° and 110° of elbow flexion and inserting properly divergent lateral pins have contributed to this outcome.

Little data exist about infections incidence after percutaneous pinning, but rates up to 2.5% of superficial[12,25] and around 0.2% of deep[36] pin tract infections have been reported. In our series we detected a single case (2.4%) of superficial pin site infection, successfully treated with oral antibiotics.

As said, unreduced type 2 PSHF can lead up to 26% of cubitus varus deformity, while in literature this percentage after treatment is stated to be between 0% and 5.9%[17]; even though this deformity was basically considered as an aesthetic problem, more recently it has been emerged to be linked to chronic pain25, ulnar neuropathy,[37] late postero-lateral instability[38] and augmented risk of lateral condyle fracture.[39] A correlation exists between Baumann angle and varus deformity (carrying angle deviation in varus of more than 10° comparing to the unaffected side) and, in fact, in our study two patients (5.3%) who developed this angular deformity, both in conservative group, are the patients whom BA are out of normal range values. Flynn criteria in these cases resulted unsatisfactory from the point of view of both cosmetics and ROM, however QuickDASH and MEPS showed only slight or mild functional deficit.

The treatment of PSHF should aim to obtain a good reduction, avoid displacement until bone healing and prevent complications. The optimal treatment for Gartland type 2 fractures has been historically widely debated. In 1991 Ippolito and Perugia[40] reported good results with trans-olecranic traction and casting; more recently Parikh et al.[41] and Spencer et al.[42] showed how closed reduction and casting is a safe and effective treatment, as well as other authors[13] stated that pinning all type 2 fractures would result in 77% of unnecessary surgery.

In an epidemiological study published in 2016 Sinikumpu et al.[24] enlightened that surgical treatment of these injuries is raised from 5.9% in 2000–2001 to 37% in 2008–2009. Skaggs et al.[12] reported very satisfactory results treating with CRPP 189 patients, with no loss of reduction, ROM limitations and angular deformity onset; they just found 4 cases (2.1%) of superficial pin-site infection treated with oral antibiotics with no sequelae. Furthermore, AAOS AUC[16] and guidelines[43] suggest CRPP as the treatment of choice for Gartland type 2 fractures.

In our study no statistically significant differences emerged concerning clinical examination and Flynn criteria and functional scores reported widely satisfactory results in both groups. Parameters that should be focused are probably two: complications (2 cases of cubitus varus in group A versus one superificial pin-tract infections in group B) and the better trend in surgical group in regards to loss of flexion and hyperextension of the affected elbow, likely related to the other notable

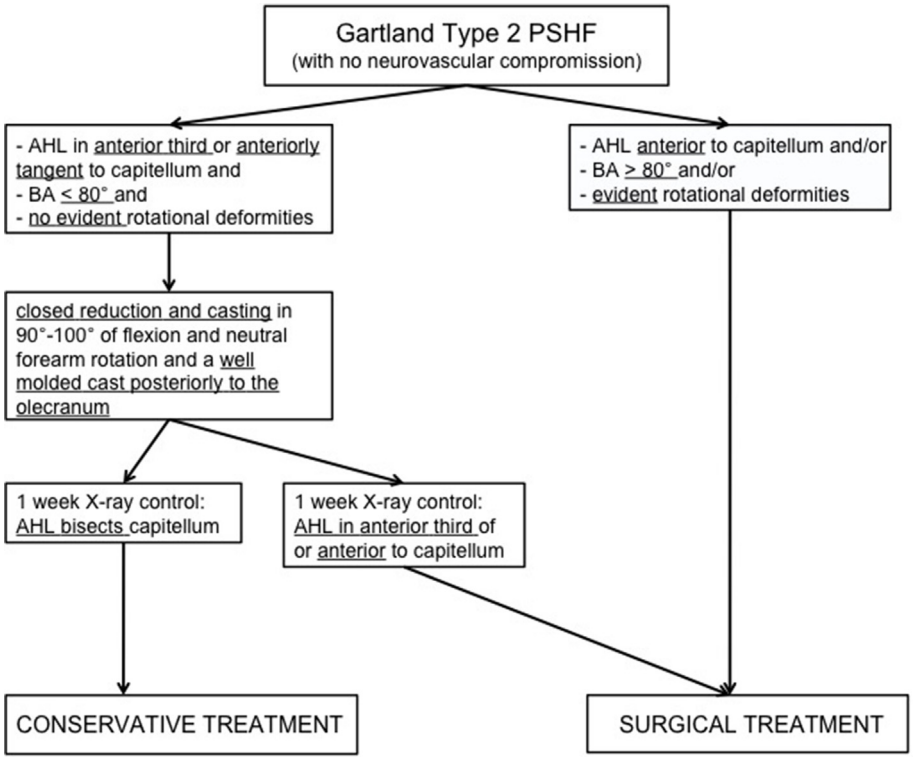

Fig. 3. Algorithm showing our decision process in treating Gartland type 2 PSHF.

datum, that is the percentage of cases in which AHL bisects the capitellum (42.1% in group A and 73.2% in group B, $p < .05$).

What is tremendously important is to set parameters which can lead surgeons choosing the most suitable treatment. Gartland's classification Wilkins modification[44] initially seemed to solve this problem, but then some intra- and inter-observer agreement troubles arose[14,15] and furthermore, as said, there is no mention of 2A and 2B distinction neither in AAOS guidelines nor in AUC. Aronson and Prager[45] proposed a distinction based on BA values (more or less than 5° compared to the unaffected side); in another paper Kao et al.[21] gave a lot of importance to the AHL, which should bisect the capitellum in patients elder than 2.5 years[46]: if this happens there should be less probability of developing elbow hyperextension and flexion limitations (and our study outcomes seems to be in agreement with this). We agree with these authors thinking that AHL and BA are the most important parameters that surgeons have to consider in order to pursue right treatment. For this reason we developed an algorithm of treatment summarizing what we think could be a reliable decision process (Fig. 3). If, in absence of evident rotational deformities, at time of fracture the AHL prolongation falls in the anterior third or is anteriorly tangent to the capitellum and there is a BA of less than 80°, a closed reduction and casting in 90–100° of elbow flexion and neutral forearm rotation with a well molded cast posteriorly to the olecranum should be pursued; at the first week X-ray control, if in lateral view AHL bisects the capitellum, conservative treatment can be continued, otherwise a surgical approach is to be chosen. As such, CRPP should be preferred if, at time of fracture, AHL is anterior to the capitellum and/or BA is more than 80° and/or there are evident rotational deformities.

Our study has certainly some limitations. It is a retrospective study, patient sample is relatively small, X-rays have been evaluated only at time of cast or pins removal and no long-term follow-up data are available.

5. Conclusion

Despite there are few studies comparing treatment options in Gartland type 2 fractures, we can find several papers stating that satisfactory outcomes should be expected with both conservative and surgical approach. And this is true, as these fractures include a wide spectrum of lesions that can be successfully treated both conservatively and surgically, as long as correct treatment criteria are known and applied.

We think that the two most important radiographic findings that can help surgeons assessing a satisfactory reduction and pursuing best treatment option, in association with evident angular and rotational deformities, are anterior humeral line and Baumann angle.

Further long-term and possibly prospective randomized studies comparing casting and surgery are needed in order to better define the best treatment option for Gartland type 2 pediatric supracondylar humeral fractures.

Funding source

Disclosures of funding for this work: none.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Pannu GS, Eberson CP, Abzug J, et al. Common errors in the management of supracondylar humerus fractures and lateral condyle fractures. *Instr Course Lect.* 2016 Feb 15;65:385–398.
2. Shrader MW. Pediatric suracondylar fractures and pediatric physeal elbow fractures. *Orthop Clin N Am.* 2008 Apr;39(2):163–171.
3. Houshian S, Mehdu B, arsen MS. The epidemiology of elbow fracture in children: analysis of 355 fractures, with special reference to supracondylar humerus fractures. *J Orthop Sci.* 2001;6(4):312–315.
4. Brubacher JW, Dodds SD. Pediatric supracondylar fractures of the distal humerus. *Curr Rev Muscoloskelet Med.* 2008;1(3-4):190–196.
5. Fransworth CL, Silva PD, Mubarak SJ. Etiology of supracondylar humerus fractures. *J Pediatr Orthop.* 1998;18(1):38–42.
6. Brauer CA, Lee BM, Bae DS, et al. A systematic review of medial and lateral entry pinning for supracondylar fractures of the humerus. *J Pediatr Orthop.*

2007;27(2):181–186.
7. Gartland JJ. Management of supracondylar fractures of the humerus in children. *Surg Gynecol Obstet.* 1959;109(2):145–154.
8. Ariyawatkul T, Eamsobhana P, Kaewpornsawan K. The necessity of fixation in Gartland type 2 supracondylar fracture of the distal humerus in children (modified Gartland type 2A and 2B). *J Pediatr Orthop B.* 2016 Mar;25(2):159–164.
9. Mazda K, Boggione C, Fitoussi F, et al. Systematic pinning of displaced extension-type supracondylar fractures: a randomized controlled trial. *J Pediatr Orthop B.* 2001;10:131–137.
10. Beaty JH, Kasser JR. The elbow region: general concepts in the pediatric patient. In: Beaty JH, Kasser JR, eds. *Rockwood and Wilkins Fractures in Children.* seventh ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2010:563–576.
11. Padman M, Warwick AM, Fernandes JA et al. Closed reduction and stabilization of supracondylar fractures of the humerus in children: the crucial factor of surgical experience. J Pediatr Orthop B; 19:298-303.
12. Skaggs DL, Sanker WN, Albrektson J, et al. How safe is the operative treatment of Gartland type 2 supracondylar humerus fracture s in children? *J Pediatr Orthop.* 2008;28:139–141.
13. Hadlow AT, Devane P, Nicol RO. A selective treatment approach to supracondylar fracture of the humerus in children. *J Pediatr Orthop.* 1996;16:104–106.
14. Heal J, Bould M, Livingstone J, et al. Reproducibility of the Gartland Classification for supracondylar humeral fractures in children. *J Orthop Surg.* 2007 Apr;15(1):12–14.
15. Leung S, Paryavi E, Herman MJ, et al. Does the modified Gartland classification clarify decision making? *J Pediatr Orthop.* 2018 Jan;38(1):22–26.
16. Appropriate use criteria for the management of pediatric supracondylar humerus fractures. Available at: http://www.aaos.org/research/appropriate_use/pshf_auc.pdf, Accessed date: 1 March 2015.
17. Moraleda L, Valencia M, Barco R, et al. Natural history of unreduced Gartland type-II supracondylar fractures of the humerus in children: a thirteen-year follow-up study. *J Bone Joint Surg Am.* 2013 Jan 2;95(1):28–34.
18. Flynn JC, Matthews JG, Benoit RL. Blind pinning of displaced supracondylar ractures of the humerus in children. Sixteen years' experience with long-term follow-up. *J Bone Joint Surg Am.* 1974;56:263–272.
19. Williamson DM, Coates CJ, Miller RK, et al. Normal characteristics of the Baumann (humerocapitellar) angle: an aid in assessment of supracondylar fractures. *J Pediatr Orthop.* 1992;12:636–639.
20. Omid R, Choi PD, Skaggs DL. Supracondylar humeral fractures in children. *J Bone Joint Surg Am.* 2008;90:1121–1132.
21. Kao HK, Lee WC, Yang WE, et al. Clinical significance of anterior humeral line in supracondylar humeral fractures in children. *Injury.* 2016 Oct;47(10):2252–2257.
22. Miranda I, Sànchez-Arteaga P, Marrachelli VG, et al. Orthopedic versus surgical treatment of Gartland type II supracondylar humerus fractures in children. *J Pediatr Orthop B.* 2014 Jan;23(1):93–99.
23. Cheng JC, Lam TP, Maffulli N. Epidemiological features of supracondylar fractures of the humerus in Chinese children. *J Pediatr Orthop.* 2001;10:63–67.
24. Sinikumpu JJ, Pokka T, Sirviö M, et al. Gartland type II supracondylar humerus fractures, their operative treatment and lateral pinning are increasing: a population-based epidemiologic study of extension-type supracondylar humerus fracture in children. *Eur J Pediatr Surg.* 2017 Oct;27(5):455–461.
25. Zorrilla S de Neire J, Prada-Cañizares A, Marti-Ciruelos R, et al. Supracondylar humeral fractures in children: current concepts for management and prognosis. *Int Orthop.* 2015 Nov;39(11):2287–2296.
26. Flynn JC, Cornwall R. Elbow: pediatrics. In: Vaccaro AR, ed. *Orthopedic Knowledge Update 8.* Rosemont, Illinois: American Academy of Orthopaedic Surgeons; 2005:705–707.
27. Flynn JC, Sarkark JF, Waters P, et al. The operative management of pediatric fractures of upper extremity. *J Bone Joint Surg Am.* 2002;84:2078–2089.
28. Farnsworth CL, Silva PD, Mubarak SJ. Etiology of supracondylar humerus fractures. *J Pediatr Orthop.* 1998;18:38–42.
29. Zamzam MM, Bakarman KA. Treatment of displaced supracondylar humeral fractures among children: crossed versus lateral pinning. *Injury.* 2009;40:625–630.
30. Mapes RC, Hennrikus WL. The effect of elbow position on the radial pulse measured by Doppler ultrasonography after surgical treatment of supracondylar elbow fractures in children. *J Pediatr Orthop.* 1998;18:441–444.
31. Battaglia TC, Armstrong DG, Schwend RM. Factors affecting forearm compartment pressures in children with supracondylar fractures of the humerus. *J Pediatr Orthop.* 2002;22:431–439.
32. Skaggs DL, Ramachandran M, Crawford H, et al. *Delaying Treatment of Supracondylar Fractures: Has the Pendulum Swung Too Far? Read at the Annual Meeting of the Pediatri.* San Diego, CA: Orthopaedic Society of North America; 2006 May 3-6.
33. Bae DS, Kadiyala RK, Waters PM. Acute compartment syindrome in children: contemporary diagnosis, treatment, and outcome. *J Pediatr Orthop.* 2001;21(5):680–688.
34. Lucas DE, Willis LM, Kingele KE. Factors predictive of early radiographic failure after closed reduction of Gartland type II supracondylar humeral fractures. *J Orthop Trauma.* 2013 Aug;27(8):457–461.
35. Pennock AT, Charles M, Moor M, et al. Potential causes of loss of reduction in supracondylar humerus fractures. *J Pediatr Orthop.* 2014 Oct-Nov;34(7):691–697.
36. Bashyal RK, Chu JY, Schoenecker PL, et al. Complications after pinning of supracondylar distal humerus fractures. *J Pediatr Orthop.* 2009;29(7):704–708.
37. Abe M, Ishizu T, Morikawa J. Posterolateral rotatory instability of the elbow after post-traumatic cubitus varus. *J Shoulder Elbow Surg.* 1997;6(4):405–409.
38. O'Driscoll SW, Spinner RJ, McKee MD, et al. Tardy posterolateral rotatory instability of the elbow due to cubitus varus. *J Bone Joint Surg Am.* 2001;83-A(9):1358–1369.
39. Davids JR, Maguire MF, Mubarak SJ, et al. Lateral condylar fracture of the humerus following post-traumatic cubitus varus. *J Pediatr Orthop.* 1994;14(4):466–470.
40. Ippolito E, Caterini R, Tudisco C, Perugia D. Le fratture sovracondiloidee dell'omero nei bambini. *GIOT.* 1991;XVII:151–159.
41. Parikh SN, Wall EJ, Foad S, et al. Displaced type II extension supracondylar humerus fractures: do they all need pinning? *J Pediatr Orthop.* 2004 Jul-Aug;24(4):380–384.
42. Spencer HT, Dorey FJ, Zionts LE, et al. Type II supracondylar humerus fractures: can some be treated nonoperatively? *J Pediatr Orthop.* 2012;32:675–681.
43. Howard A, Mulpuri K, Abel MF, et al. American Academy of Orthopaedic Surgeons. The treatment of pediatric supracondylar humerus fractures. *J Am Acad Orthop Surg.* 2012;20(5):320–327.
44. Wilkins KE. Fractures and dislocation of the elbow region. In: Rockwood CA, Wilkins KE, King RE, eds. *Fractures in Children.* Philadelphia, PA: JB Lippincott; 1984:365–575. ; vol. 3.
45. Aronson DD, Prager BI. Supracondylar fractures of the humerus in children: a modified technique for closed pinning. *Clin Orthop Relat Res.* 1987;219:174–184.
46. Rogers LF, Malave Jr S, White H, et al. Plastic bowing, torus and greenstick supracondylar fractures of the humerus: radiographic clues to obscure fractures of the elbow in children. *Radiology.* 1978;128:145–150.