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Analysis of the factors causing tight cast syndrome after closed reduction and casting of pediatric distal radius fractures

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ABSTRACT

Objective: The aim of this study was to evaluate the most important factors which can cause "tight cast syndrome" (TCS) in pediatric patients with distal radius fractures.
Methods: Patients, who were at or under 15 years old and treated conservatively with an diagnosis of distal radius fracture between August 2015 and August 2017 were included in to the study. Fifty four patients, who had been found to experience TCS were accepted as group 1 and sixty-two patients without TCS as group 2. Cast index, pre-/post reduction translation, pre-/post reduction angulation, localization and displacement of the fracture, need for re-manipulation, and presence of associated distal ulna fracture were evaluated for both groups. Statistical analysis was performed to evaluate cut off value for cast index values for both TCS and loss of reduction and logistic regression analysis of the other possible factors.
Results: Pre-/post-reduction translation (over 50% and 10%, respectively) (odds ratios:0.167 and 0.524, respectively), a cast index value below than 0.775 (odds ratio:3.080), displaced type fracture (odds ratio:8.028), presence of re-manipulation (odds ratio:0.131) and associated distal ulna fracture (odds ratio:2.029) were found to be statistically significantly important for the occurrence of TCS. The most important factors were decreased cast index value and presence of initially displaced type fracture. Loss of reduction (LOR) risk was found to be increased in patients with a cast index value of greater than 0.875.
Conclusion: One should be very careful when following a pediatric patient who have a displaced distal radius fracture which has initial/post reduction translation in AP plane, which is associated with distal ulna fracture, which required re-manipulation and most importantly which cast index is under than 0.775 in terms of occurrence of TCS. We recommend obtaining a cast index value between 0.775 and 0.875 to prevent both TCS and LOR.
Level of evidence: Level III, Therapeutic study.

Introduction

Fractures of the radius account for nearly 35–45% of all pediatric bone fractures[1] and most of these fractures are in the distal radius.[1–5] Treatment for pediatric distal radius fractures (DRF) is usually conservative with casting either after reduction or without reduction according to the acceptability of the fracture position.[6,7]

Re-displacement can occur in these fractures due to several risk factors.[8] Poor casting technique has been reported to be a crucial factor for re-displacement of the fracture fragments.[9–13] Proper molding of the cast is very important, and casting is not free of complications. It has been reported that of patients with cast issues, "tight cast" constitutes 23%.[14] Recently, A'Court et al reported that "tightly applied cast" was the most common cause (40%) for complaints related to casting.[15] Careful application of casts and close follow-up of patients after casting are mandatory to prevent the possible catastrophic complications such as compartment syndrome and Volkmann's contracture.

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In daily practice it is common for pediatric patients with long or short arm casts to visit the Emergency Department with complaints of swollen fingers and pain, and this is firstly named as "tight cast syndrome" (TCS) by us, since there is no clear information about definition of this very important condition in the literature (Fig. 1). In our routine practice, these patients are treated either with cast removal and splinting or bivalve opening of the cast. Re-manipulation and casting after subsidence of swelling and pain is our preferred method in these circumstances and occasionally, operative fixation may be necessary. We hypothesized that several factors such as amount of the energy that caused the trauma, fracture characteristics or a tightly applied cast could play role in the occurrence of TCS. To the best of our knowledge there is no data in literature about the possible causative factors of TCS which can result in devastating complications after casting of pediatric distal radius fractures. The aim of this study was to evaluate the most crucial factors which can cause "tight cast syndrome" in pediatric patients with distal radius fractures.

Materials and methods

Approval for the study was granted by the Local Ethics Committee (2017/12). Our hospital's digital database was reviewed to identify patients who were at or under 15 years old with an ICD code (S52.5) of distal radius fracture between August 2015 and August 2017. A total of 1475 patients were identified. After excluding 32 open fractures and 519 diagnoses incorrectly registered (forearm fractures), 924 of these patients had closed distal radius fractures. The medical records of the patients were evaluated retrospectively. A total of 92 (9.9%) patients presented at the Emergency Department with TCS and were treated with bivalve opening of the cast. Of these patients who had experienced TCS, 54 with proper postero-anterior (PA) and lateral wrist radiographs of both injury and post-reduction and regular follow-up records until healing were included in the study as Group 1 Over the list, a hundred medical record numbers of patients who did not experience TCS were selected randomly by an orthopedic resident who did not take a part in the study. Sixty-two out of these 100 patients had proper radiographs and also had regular medical records until healing. As a result, group 2 was consisted of these 62 randomly selected patients who did not experience TCS. Plaster of Paris was used for every single distal radius fracture casting.

Fig. 1. Clinical picture of a patient with "tight cast syndrome".

The categorical data of all patients encountered in the study are shown in Table 1. Below elbow casting was mostly used for epiphyseal and metaphyseal fractures which were considered as stable, above elbow casting were used for metaphyseal fractures which were considered as unstable. Cut-off value of cast index was obtained after receiver operating characteristic (ROC) curve analysis about occurrence of TCS. Loss of reduction (LOR) was accepted as change of 15° angulation in coronal alignment and/or angulation in the sagittal plane up to 30° if more than five years of growth remaining and 5° less for each year less than five.[16] Patients with LOR were evaluated and ROC curve analysis was obtained according to cast index values. Age, pre-reduction and post-reduction lateral plane angulation, and cast index,[8] were also evaluated as continuous data. Cast index measurement was performed by dividing inner diameter of cast on lateral to inner diameter of cast on antero-posterior (both at fracture site) as described by Chess et al[8] (Fig. 2).

All measurements were performed by the second author who was a fifth year training resident in orthopaedics and traumatology.

Statistical analysis

Statistical analysis was performed using SPSS version 17 for Windows. The Student's *t*-test was used to compare continuous data. Univariate analysis was performed with Pearson's Chi-squared test. Comparisons were made between the groups with and without TCS, then binary logistic regression analysis was performed to identify independent clinical predictors for TCS. After performing a likelihood ratio Chi-squared test, variables with $p < 0.25$[17] were selected for the multivariate model. The regression model fit was estimated with the Hosmer–Lemeshow goodness-of-fit test. Adjusted odds ratios (OR) and 95% confidence intervals (CI) were derived using the method of maximum likelihood. A value of $p < 0.05$ was accepted as statistically significant.

MedCalc Statistical Software version 15.8 (MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org; 2015) was used for the receiver operating characteristic (ROC) curve analysis.

Results

ROC curve analysis was performed for cast index measurements. The cut-off value for the occurrence of TCS was found to be 0.775 (sensitivity: 70.4%, specificity 67.7%) (area under the curve: 0.716, 95% confidence interval: 0.625–0.796, significance level: <0.0001)

Table 1
Categorical data of all patients encountered in the study.

Variable		
Gender	Girl (n:87)	Boy (n:29)
Associated ulna distal fracture	Present (n:39)	Absent (n:77)
Localization of the fracture	Epiphyseal (n:36)	Metaphyseal (n:80)
Type of fracture	Displaced (n:94)	Nondisplaced (n:22)
Type of applied cast	Above elbow (n:60)	Below elbow (n:56)
Necessity of initial remanuplation	Present (n:7)	Absent (n:109)
Initial coronal plane translation	Above 50% of fracture line (n:11)	Below 50% of fracture line (n:105)
Post-reduction coronal plane translation	Above 10% of fracture line (n:11)	Below 10% of fracture line (n:105)
Cast index value	Above 0.775 (n:59)	Below 0.775 (n:57)
Loss of reduction	Present (n:10)	Absent (n:106)

Fig. 2. Measurement method of cast index.

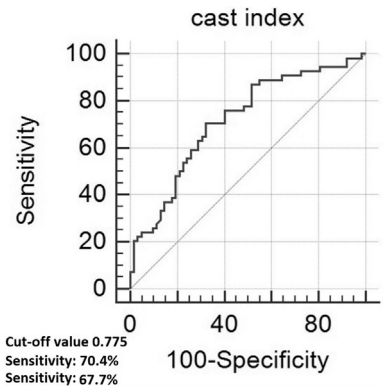

Fig. 3. ROC analysis of cast index values.

(Fig. 3). The cut off value about LOR was found to be 0.875 (sensitivity: 60%, specificity: 89.6) (area under the curve: 0.742, 95% confidence interval: 0.653–0.819, significance level: 0.0061) (Fig. 4). After applying the Chi-squared test, it was observed that the presence of associated distal ulna fracture, displaced fracture, cast index value < 0.775, initial translation of the fracture more than half of the fracture line on AP radiograph, translation of the fracture >10% of the fracture line on AP radiograph after the reduction, and finally re-manipulated fractures were all prone to TCS (p values: 0.02- <0.001- <0.001- 0.01- 0.01- 0.03, respectively) (Table 2). There was not a statistically significance difference between patients with cast index below than or upper than 0.775 according to LOR (p = 0.47) (Table 3). There was no statistically significant difference between males and females, epiphyseal and

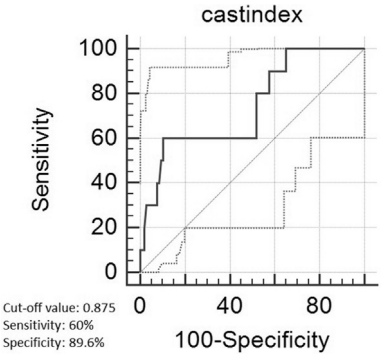

Fig. 4. ROC analysis of the relationship of cast index and loss of reduction.

metaphyseal fractures or short and long casts (p values = 0.28- 0.36- 0.69, respectively) (Table 2). After evaluation of continuous data with the Student's t-test, cast index measurements showed a statistically significant difference between the two groups (p < 0.001). Other variables such as age, angulation in the sagittal plane on either pre- or post-reduction radiographs did not show any statistically significant difference (p values = 0.79- 0.67- 0.82, respectively) (Table 4).

After binary logistic regression analysis, it was clear that if the fracture was displaced and cast index was <0.775, the possibility of TCS was high (Table 5)

TCS occurrence was observed meanly 1.55 ± 1.07 (1–6) days after the casting procedure.

Discussion

There are many studies which have addressed the risk factors for loss of reduction (LOR) in pediatric distal radius fractures[1–4,7,9–13] and most of these have drawn attention to proper casting with adequate molding. Preventing LOR is mandatory and preventing complications in the treatment is also of the utmost importance. To be best of our knowledge, there are no studies in literature about the frequently seen TCS after manipulation and casting of pediatric distal radius fractures. The results of this study showed that this important issue, in other words, "TCS", was mostly associated with initially displaced fractures which were treated with manipulation and casting with a cast index value < 0.775. It was also observed that risk of LOR was increased with a cast index value of upper than 0.875.

Following a bone fracture, swelling develops around the fracture site due to hematoma from ruptured vessels, soft tissue injury and inflammation.[18] Obtaining the alignment of the extremity by reduction and immobilization with casting or splinting relieves the patient's pain and prevents further soft tissue injury while maintaining the reduction. Most pediatric distal radius fractures are treated conservatively.[1–4,7] However, in some circumstances conservative treatment may be unsuccessful because of LOR or complications of casting.

There are several complications of casting such as wet and soiled cast, tight cast, loose cast and pressure sores.[19,20] There have been many studies in literature about the complications of a loose cast that highlight LOR. However, no study could be found about tight cast which can result in non-compensatory complications. Many litigations with excessive costs have been brought because of tight cast.[15] Therefore, recognition of possible reasons and how to avoid these can be significant.

Cast index was first defined by Chess et al,[10] who stated in an anthropometric study that the ratio of the sagittal plane and

Table 2
Comparison of the categorical variables for the patients with and without tight cast syndrome.

	Tight Cast Syndrome Present (n:54)	Tight Cast Syndrome Absent (n:62)	P value[a]
Gender (girl/boy)	43/11	44/18	0.28
Fracture localization (metaphyseal/epiphyseal)	35/19	45/17	0.36
Associated ulna distal fracture (present/absent)	24/30	15/47	**0.02**
Type of fracture (displaced/nondisplaced)	52/2	42/20	**<0.001**
Type of cast (below elbow-above elbow)	25/29	31/31	0.69
Cast index (<0.775/>0.775)	37/17	20/42	**<0.001**
Pre-reduction translation (below than 50%/upper than 50%)	45/9	60/2	**0.01**
Post-reduction translation (below than 10%/upper than 10%)	45/9	60/2	**0.01**
Necessity of initial re-manipulation (present/absent)	6/48	1/61	**0.03**

Bold indicates statistical significance.
[a] Chi-squared test.

Table 3
Relationship of loss of reduction and cast index values[a].

	Cast index below than 0.775	Cast index upper than 0.775	Totally
Loss of reduction present	4	6	10
Loss of reduction absent	53	53	106
Totally	57	59	116

[a] p: 0.47 (Chi-squared test).

coronal plane of the pediatric distal forearm was normally 0.7. Consequently, it was defined that in a well molded cast, the cast index should be normally around 0.7. Similarly, Bae et al[21] stated that a cast index >0.7 was associated with a high rate of LOR. More recently, Debnath et al[22] reported that a cast index value > 0.84 was more consistent with the risk of LOR in distal forearm fractures of pediatric patients with 85% sensitivity and 81% specificity. In the current study, after performing ROC curve analysis of cast index measurements of the patients with and without TCS, it was determined that patients with a value < 0.775 were more prone to TCS with 70.4% sensitivity and 67.7% specificity. In our study it was also observed that LOR risk increased in patients with a value of upper than 0.875. After grouping the patients into two groups according to this finding, it was seen that TCS was observed in patients with a cast index <0.775 more frequently and this finding was statistically significant ($p < 0.001$, Table 1). This was also determined to be one of the strongest predictor of TCS after binary logistic regression analysis ($p = 0.012$, Table 4).

As expected, TCS was observed to be more likely to develop in patients with displaced fractures. This finding is probably a result of higher energy mechanism of trauma and therefore a proportionally higher degree of soft tissue injury that results in more edema and extravasation. The current study results also showed that initial translation of the fracture of more than half of the fracture line and more than 10% after reduction were also cautionary factors for TCS.

Associated distal ulna fracture may also be present in a high energy injury and has been reported as a predictor of an unstable fracture pattern.[23] According to the current studies results, patients with associated distal ulna fractures experienced TCS statistically

Table 5
Odds ratios and p values of important independent variables about occurring tight cast syndrome as a result of binary logistic regression test.

Independent variable	Odds ratio	95% CI	p value
Displaced fracture	8.028	1.538–41.915	**0.014**
Cast index lower than 0.775	3.080	1.286–7.379	**0.012**
Presence of associated ulna distal fracture	2.029	0.747–5.514	0.165
Long arm cast	1.160	0.559–2.409	0.870
Epiphyseal fracture	0.696	0.316–1.533	0.367
Girls	0.625	0.265–1.477	0.537
Post-reduction translation more than 10%	0.524	0.367–0.747	0.471
Initial translation more than 50%	0.167	0.034–0.809	0.484
Need for remanuplation	0.131	0.015–1.126	0.585

Bold indicates statistical significance. CI: Confidence interval.

significantly more often ($p = 0.02$, Table 1). The binary logistic regression analysis also showed that the odds ratio was 2.029 (Table 4). In some cases, an immediate re-reduction maneuver may be necessary, especially in centers which closed reduction procedures are performed in the Emergency Department without fluoroscopic control. Re-manipulation creates an additional soft tissue injury and this predisposes the limb to additional swelling. As expected, TCS was observed more commonly among the re-manipulated cases in the current study group. This finding was also statistically significant ($p = 0.03$, Table 1).

There are several limitations to this study, the most important of which is that it was a retrospectively designed study. All the measurements were performed by a single author and intra- and inter-observer reliability was not evaluated. Time between injury and casting could not evaluated because this study was retrospectively designed. Randomly selected patients' data who did not experience TCS from a large population (62 out of 832) were used as a control group. This method may have some impact on the results. Another very important limitation of this study is that; sensitivity and specificity values of ROC curve analysis about both TCS and LOR occurrence are not remarkably high. An ideal ROC curve analysis was considered to have an area under the ROC curve

Table 4
Comparison of the continuous variables for the patients with and without tight cast syndrome.

	Tight cast syndrome present (n:54) [mean ± standard deviation (minimum-maximum)]	Tight cast syndrome absent (n:62) [mean ± standard deviation (minimum-maximum)]	p value[a]
Age	9.94 ± 3.26 (3–15)	10.09 ± 3.02 (3–15)	0.79
Cast index	0.74 ± 0.08 (0.56–0.98)	0.80 ± 0.07 (0.61–0.98)	**<0.001**
Pre-reduction sagittal plane angulation	15.04 ± 11.71 (0–35)	14.14 ± 10.91 (0–37)	0.67
Post-reduction sagittal plane angulation	3.20 ± 4.37 (0–16.7)	2.98 ± 5.71 (0–3.20)	0.82

Bold indicates statistical significance.
[a] Student's *t*-test.

of greater than or equal to 0.80 with the lower limit of the 95% confidence interval greater than 0.50.[24] In this current study, although lower limits of 95% confidence intervals are ideal, areas under the ROC curve were not high enough (0.716 and 0.742, respectively). Sensitivity and specificity values can be increased in a larger study population.

In conclusion; the cast index value should be between 0.775 and 0.875 to prevent both TCS and LOR.

The results of this study have shown that in respect of the development of TCS, very careful follow-up is necessary for pediatric patients with a displaced distal radius fracture with initial/post reduction translation in the AP plane, or with a concomitant distal ulna fracture, or which required re-manipulation and most importantly with a cast index <0.775. In an unstable fracture, if the reduction is acceptable and cast index value is below than 0.775, we recommend a very close follow-up of the patient instead of revising the cast. Similarly, if the cast index value is above than 0.875, close follow-up is necessary because of the risk of LOR. Currently, we prefer to wrap at least two layers of cast cotton to decrease the risk of a lower cast index value. We emphasize the importance of accurate three point molding of the cast more than tightly applied cast.

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Conflicts of interest

Author Ali Turgut, author Serkan Erkuş, author Anıl Koca, author Levent Payzıner, author Ali Osman Çiçek and author Önder Kalenderer declare that they have no conflict of interest.

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