Predicting Success of Growth Modulation Surgery in Late Onset Tibia Vara (LOTV)

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INTRODUCTION:

Growth modulation surgery with hemi-epiphyseal tether plating in LOTV has variable results in prior literature. We sought to confirm that skeletal maturity, patient body weight, and deformity severity could be used to predict the odds of deformity correction in our patient population. We also hypothesized that larger, more rigid implant design would also predict success.

METHODS: We retrospectively reviewed patients with LOTV treated with lateral tension band plate (LTBP) guided growth at a tertiary pediatric multi-hospital facility over a 10 year period. Pre and post operative radiographic deformity markers, implant data, and demographic data was recorded. Included patients had final radiographs for analysis at minimum 2 year follow up, or last radiographs prior to hardware removal/subsequent surgery. Treatment success was defined as normalization of varus alignment or any valgus overcorrection of the limb. Uni and multivariate analysis were performed to identify odds of a successful outcome based on recorded risk and treatment factors.

RESULTS: 47 patients (74 limbs) met our inclusion criteria for review. 61% (45) limbs were successfully treated. Severity of deformity, skeletal maturity, and preoperative weight all significantly correlated with treatment outcome. A 1 degree increase in medial proximal tibial angle (MPTA) or 1 degree increase in valgus mechanical tibiofemoral angle (mTFA) increased the odds of successful treatment by 1.22($p<.001$) and 1.2($p<.001$) respectively. When adjusting for MPTA and preoperative BMI on multivariate analysis, greater than 3 years of growth remaining increased odds of successful treatment 27.2 times ($p=.001$) Implant design (screw size, cannulated or solid screws, screw number, and plate type) did not correlate with odds of treatment success.

DISCUSSION AND CONCLUSION: In our patient cohort, less severe deformity, greater age of growth remaining, and decreased patient body weight all predicted treatment success of LOTV with LTBP which corroborates prior studies' results. We were not able to find a significant treatment effect from different implant options, however this effect may be limited by our sample size. This information gives helpful insight to narrow treatment indications with this technique for LOTV, and provide families with better estimates of success based on preoperative risk factors.

Table 1. Descriptive summary for demographic and clinical data

Characteristic	
Patient level	**N = 47[1]**
Age at first surgery	12.30 (10.35, 13.18)
Sex	
Female	12 (26%)
Male	35 (74%)
Race/ethnicity	
African American	29 (62%)
Non-African American	18 (38%)
Height (m)	1.54 (1.49, 1.64)
Weight (kg)	72 (55, 94)
Pre-op BMI	
< 30	23 (49%)
>= 30 to <40	16 (34%)
>= 40	8 (17%)
BMI 1-year post-op	
< 30	18 (41%)
>= 30 to <40	13 (30%)
>= 40	13 (30%)
(Missing)	3
BMI 2-year post-op	
< 30	13 (35%)
>= 30 to <40	16 (43%)
>= 40	8 (22%)
(Missing)	10
Limb level	**N = 74[1]**
Laterality	
Left	43 (58%)
Right	31 (42%)
Chronologic age (Preop)	11.99 (9.78, 13.13)
Bone Age (Preop)	12.12 (11.21, 13.53)
Years of Growth Remaining	
< 2 years	13 (18%)
2 to 3 years	24 (32%)
> 3 years	37 (50%)
Preop - all hip physes open	
Yes	41 (55%)
No	33 (45%)
Preop - tri-rad closed, fem open	
Yes	24 (32%)
No	50 (68%)
Preop any prox fem closure	
Yes	11 (15%)
No	63 (85%)
Height (m)	1.53 (1.45, 1.63)
Weight (kg)	70 (48, 94)
BMI	
< 30	38 (51%)
>= 30 to <40	22 (30%)
>= 40	14 (19%)
BMI 1 yr post	
< 30	30 (43%)
>= 30 to <40	19 (28%)
>= 40	20 (29%)
(Missing)	5
BMI 2 yr post	
< 30	22 (39%)
>= 30 to <40	21 (37%)
>= 40	14 (25%)
(Missing)	17

[1] Median (IQR); n (%)

Table 2. Preop and treatment comparisons by treatment outcome on limb level, N=74

Characteristic	Overall, N = 74[1]	Failure, N = 29[1]	Success, N = 45[1]	p-value[2]
Sex				0.102
Female	18 (24%)	10 (34%)	8 (18%)	
Male	56 (76%)	19 (66%)	37 (82%)	
Race/ethnicity				0.714
African American	44 (59%)	18 (62%)	26 (58%)	
Non-African American	30 (41%)	11 (38%)	19 (42%)	
Years of Growth Remaining				**<0.001**
<2 years	13 (18%)	10 (34%)	3 (6.7%)	
2 to 3 years	24 (32%)	12 (41%)	12 (27%)	
> 3 years	37 (50%)	7 (24%)	30 (67%)	
Height (m)	1.53 (1.45, 1.63)	1.54 (1.49, 1.61)	1.52 (1.42, 1.65)	0.719
Weight (kg)	70 (48, 94)	84 (66, 105)	63 (42, 88)	**0.017**
Pre-op BMI				0.067
< 30	38 (51%)	10 (34%)	28 (62%)	
>= 30 to <40	22 (30%)	11 (38%)	11 (24%)	
>= 40	14 (19%)	8 (28%)	6 (13%)	
Screw # per plate				0.994
2	51 (69%)	20 (69%)	31 (69%)	
4	23 (31%)	9 (31%)	14 (31%)	
Screw Diam (mm)				0.767
3.5	14 (19%)	5 (17%)	9 (20%)	
4.5	60 (81%)	24 (83%)	36 (80%)	
Screw Type (Cann/Solid)				0.254
Cannulated	18 (24%)	5 (17%)	13 (29%)	
Solid	56 (76%)	24 (83%)	32 (71%)	
preop - all hip physes open				**<0.001**
No	33 (45%)	21 (72%)	12 (27%)	
Yes	41 (55%)	8 (28%)	33 (73%)	
preop- tri-rad closed, fem open				0.067
No	50 (68%)	16 (55%)	34 (76%)	
Yes	24 (32%)	13 (45%)	11 (24%)	
pre-op any prox fem closure				**0.003**
No	63 (85%)	20 (69%)	43 (96%)	
Yes	11 (15%)	9 (31%)	2 (4.4%)	
Hinge Plate				**0.011**
No	64 (86%)	21 (72%)	43 (96%)	
Yes	10 (14%)	8 (28%)	2 (4.4%)	
MAD preop	-40 (-60, -22)	-57 (-74, -40)	-27 (-45, -16)	**<0.001**
mTFA preop	-12 (-17, -7)	-16 (-23, -12)	-9 (-13, -5)	**<0.001**
mLDFA preop	90.4 (88.9, 93.5)	91.8 (89.0, 97.0)	90.0 (88.8, 93.2)	0.139
MPTA preop	82.1 (78.0, 84.5)	78.9 (75.5, 83.8)	82.8 (81.4, 86.0)	**0.005**
MAZone preop				**<0.001**
-3	44 (59%)	24 (83%)	20 (44%)	
-2	18 (24%)	5 (17%)	13 (29%)	
-1	12 (16%)	0 (0%)	12 (27%)	

[1] n (%); Median (IQR)

[2] Pearson's Chi-squared test; Fisher's exact test; Wilcoxon rank sum test

Table 2. Preop and treatment comparisons by treatment outcome on limb level, N=74

Characteristic	Overall, N = 74[1]	Failure, N = 29[1]	Success, N = 45[1]	p-value[2]
Sex				0.102
Female	18 (24%)	10 (34%)	8 (18%)	
Male	56 (76%)	19 (66%)	37 (82%)	
Race/ethnicity				0.714
African American	44 (59%)	18 (62%)	26 (58%)	
Non-African American	30 (41%)	11 (38%)	19 (42%)	
Years of Growth Remaining				**<0.001**
<2 years	13 (18%)	10 (34%)	3 (6.7%)	
2 to 3 years	24 (32%)	12 (41%)	12 (27%)	
> 3 years	37 (50%)	7 (24%)	30 (67%)	
Height (m)	1.53 (1.45, 1.63)	1.54 (1.49, 1.61)	1.52 (1.42, 1.65)	0.719
Weight (kg)	70 (48, 94)	84 (66, 105)	63 (42, 88)	**0.017**
Pre-op BMI				0.067
< 30	38 (51%)	10 (34%)	28 (62%)	
>= 30 to <40	22 (30%)	11 (38%)	11 (24%)	
>= 40	14 (19%)	8 (28%)	6 (13%)	
Screw # per plate				0.994
2	51 (69%)	20 (69%)	31 (69%)	
4	23 (31%)	9 (31%)	14 (31%)	
Screw Diam (mm)				0.767
3.5	14 (19%)	5 (17%)	9 (20%)	
4.5	60 (81%)	24 (83%)	36 (80%)	
Screw Type (Cann/Solid)				0.254
Cannulated	18 (24%)	5 (17%)	13 (29%)	
Solid	56 (76%)	24 (83%)	32 (71%)	
preop - all hip physes open				**<0.001**
No	33 (45%)	21 (72%)	12 (27%)	
Yes	41 (55%)	8 (28%)	33 (73%)	
preop- tri-rad closed, fem open				0.067
No	50 (68%)	16 (55%)	34 (76%)	
Yes	24 (32%)	13 (45%)	11 (24%)	
pre-op any prox fem closure				**0.003**
No	63 (85%)	20 (69%)	43 (96%)	
Yes	11 (15%)	9 (31%)	2 (4.4%)	
Hinge Plate				**0.011**
No	64 (86%)	21 (72%)	43 (96%)	
Yes	10 (14%)	8 (28%)	2 (4.4%)	
MAD preop	-40 (-60, -22)	-57 (-74, -40)	-27 (-45, -16)	**<0.001**
mTFA preop	-12 (-17, -7)	-16 (-23, -12)	-9 (-13, -5)	**<0.001**
mLDFA preop	90.4 (88.9, 93.5)	91.8 (89.0, 97.0)	90.0 (88.8, 93.2)	0.139
MPTA preop	82.1 (78.0, 84.5)	78.9 (75.5, 83.8)	82.8 (81.4, 86.0)	**0.005**
MAZone preop				**<0.001**
-3	44 (59%)	24 (83%)	20 (44%)	
-2	18 (24%)	5 (17%)	13 (29%)	
-1	12 (16%)	0 (0%)	12 (27%)	

[1] n (%); Median (IQR)

[2] Pearson's Chi-squared test; Fisher's exact test; Wilcoxon rank sum test

Table 4. Logistic regression analysis for successful treatment potential factors, main predictor = preop MPTA

Characteristic	Univariable OR (95% CI)*	p-value	Multivariable 1 OR (95% CI)	p-value	Multivariable 2 OR (95% CI)	p-value	Multivariable 3 OR (95% CI)	p-value
Preop MPTA	1.22 (1.09, 1.37)	**<0.001**	1.21 (1.06, 1.38)	**0.009**	1.31 (1.09, 1.57)	**0.006**	1.25 (1.08, 1.46)	**0.005**
Years of growth remaining								
> 3 years	14.3 (3.09, 66.0)	**<0.001**			27.2 (5.17, 142)	**0.001**		
2 to 3 years	3.33 (0.73, 15.2)	0.120			8.07 (1.41, 46.1)	**0.038**		
< 2 years	Reference group				Reference group			
Preop BMI								
< 30	3.73 (1.04, 13.45)	**0.044**			3.36 (0.57, 20.0)	0.172	1.57 (0.26, 9.64)	0.595
>= 30 to <40	1.33 (0.35. 5.14)	0.676			2.54 (0.39. 16.7)	0.343	2.06 (0.33. 12.7)	0.417
>= 40	Reference group				Reference group		Reference group	
Preop physeal maturity								
All hip physes open	7.22 (2.53, 20.6)	**<0.001**					7.55 (1.96, 29.0)	**0.001**
Tri-rad closed, fem open	0.40 (0.15, 1.08)	0.071	0.24 (0.07, 0.88)	**0.020**				
Any prox fem closure	0.10 (0.02, 0.52)	**0.006**	0.09 (0.01, 0.83)	**0.010**				

*OR = Odds Ratio; CI = confidence intervalS

Robust sandwich estimator used to account for correlations within subjects (patients with 2 limbs)

Multivariable model 1 as proposed by Walker et al: preop MPTA + Triradiate closed + Any proximal femur closed.

Multivariable model 2 (our own exploratory model) = MPTA + years of growth remaining + preop BMI

Multivariable model 3 (our own exploratory model) = MPTA + preop BMI + all hips open

Table 5. Logistic regression analysis for successful treatment potential factors, main predictor = preop MPTA

Characteristic	Univariable OR (95% CI)*	p-value*	Multivariable 1 OR (95% CI)	p-value	Multivariable 2 OR (95% CI)	p-value
mTFA preop	1.20 (1.10, 1.31)	**<0.001**	1.20 (1.07, 1.35)	**0.003**	1.21 (1.08, 1.35)	**0.002**
Years of growth remaining						
> 3 years	14.3 (3.09, 66.0)	**<0.001**	8.24 (1.84, 36.9)	**0.026**		
2 to 3 years	3.33 (0.73, 15.2)	0.120	2.63 (0.59, 11.7)	0.308		
< 2 years	Reference group		Reference group			
Preop BMI						
< 30	3.73 (1.04, 13.45)	**0.044**	0.69 (0.09, 5.11)	0.697	0.41 (0.05, 3.58)	0.368
>= 30 to <40	1.33 (0.35, 5.14)	0.676	0.88 (0.13, 6.10)	0.890	0.89 (0.13,6.05)	0.897
>= 40	Reference group		Reference group		Reference group	
Preop physeal maturity						
All hip physes open	7.22 (2.53, 20.6)	**<0.001**			4.63 (1.23, 17.4)	**0.016**
Tri-rad closed, fem open	0.40 (0.15, 1.08)	0.071				
Any prox fem closure	0.10 (0.02, 0.52)	**0.006**				

*OR = Odds Ratio; CI = confidence interval

Robust sandwich estimator used to account for correlations within subjects (patients with 2 limbs)

Multivariable model 1 (our own exploratory model) = mTFA + years of growth remaining + preop BMI

Multivariable model 2 (our own exploratory model) = mTFA + preop BMI + all hips open