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Poster #122

Skeletal Maturity Confers Increased Intra-Articular Pathology in Adolescent Patients With ACL Injury

Todd Phillips, MD[1]; Brian Sullivan, MD[1]; Zach Terner, PhD[2]; Neal Goldenberg, MD[3]; Brett Heldt, MD[1]; Raymond Guo, MD[1]; Theodore Shybut, MD[4]

- [1]Department of Orthopedics, Baylor College of Medicine, Houston, TX
- [2]MITRE Corporation, Arlington, VA
- [3]Cheshire Medical Center/Dartmouth Health, Keene, NH
- [4]Southern California Orthopedic Institute

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Objective

- The purpose of this study was to:
  1) To assess differences in incidence of intra-articular pathology between skeletally immature and skeletally mature patients who underwent primary ACLR for an acute ACL injury
  2) To analyze trends in meniscal and chondral surgical treatments based upon skeletal maturity and identify significant predictors of intra-articular pathology

Materials and Methods

- A single center retrospective cohort study of acute, primary ACL reconstructions
- IRB Approved.
- Surgical case logs were queried by CPT code 29888 to identify potential subjects from January 2012 to April 2020.
- Included subjects were aged 21 and below

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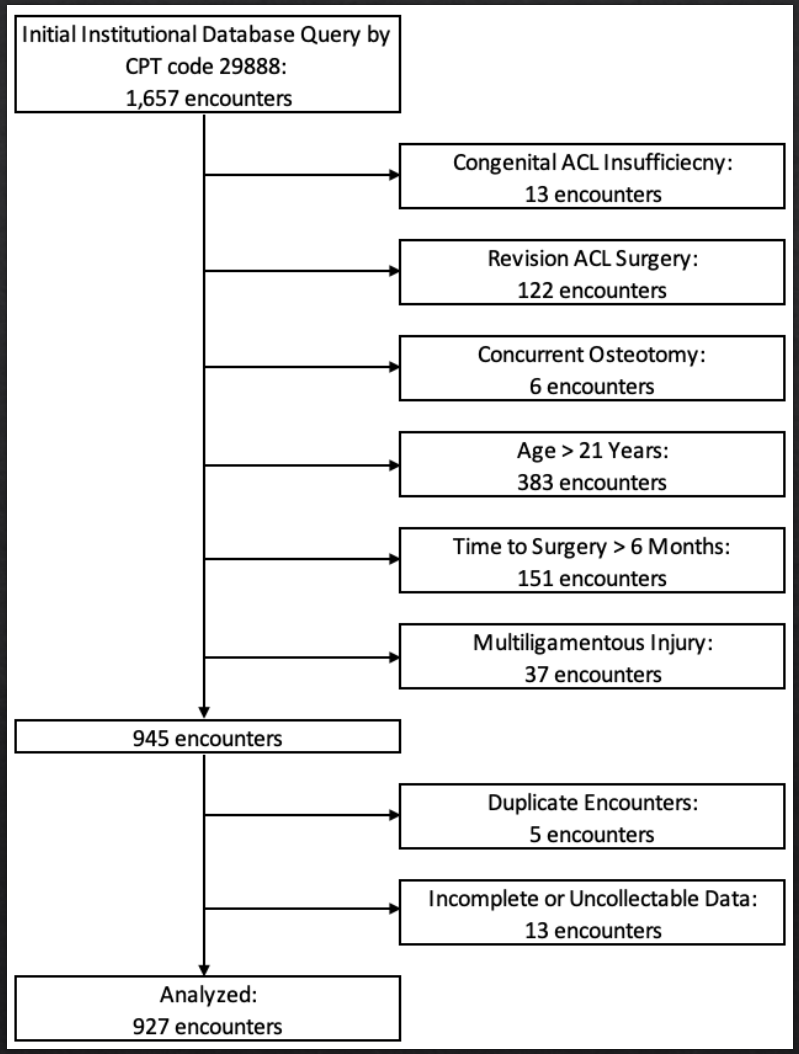
CONSORT Flow Diagram



Materials and Methods

- Skeletal maturity was determined via knee imaging (XR, MRI)
- Meniscal and chondral injury characterized by involved compartment, location, pattern.
- Logistic regression was utilized to identify predictors of injury. Interaction variables were included to parse specific impacts of non-independent predictors.

Results

- Skeletally mature patients were more likely to have medical meniscus tears compared to skeletal immature patients
- Skeletally mature patients were more likely to have tears within the body compared to skeletal immature patients
- Skeletally mature patients were more likely to have radial and complex tears compared to skeletal immature patients
- Skeletally immature patients frequently sustained vertical-longitudinal tears in the posterior horn

Meniscal Injury - Location, Pattern, & Treatment

	Skeletally Mature	Skeletally Immature	p-value
n (%)	738	149	
Meniscus Injury			
Medial Meniscus Tear[a]	297 (40.2%)	47 (31.5%)	**<.001**
Lateral Meniscus Tear[b]	441 (59.8%)	102 (68.5%)	.274
Bicompartmental Meniscus Tear	165 (22.4%)	25 (16.8%)	**.006**
Medial Meniscus Tear Location			
Anterior Horn	2 (0.6%)	1 (2.1%)	.319
Body	7 (2.4%)	1 (2.1%)	.923
Posterior Horn	185 (62.3%)	23 (48.9%)	.082
Posterior Horn-Body	31 (10.4%)	5 (10.6%)	.967
Root	13 (4.4%)	3 (6.4%)	.544
Meniscocapsular	15 (5.1%)	5 (10.6%)	.128
Bucket Handle	44 (14.8%)	9 (19.1%)	.444
Medial Meniscus Tear Pattern			
Vertical-Longitundinal	161 (54.2%)	25 (53.2%)	.897
Horizontal	11 (3.7%)	1 (2.1%)	.584
Oblique	13 (4.4%)	3 (6.4%)	.544
Radial	11 (3.7%)	2 (4.3%)	.854
Undersurface	13 (4.4%)	1 (2.1%)	.468
Bucket Handle	44 (14.8%)	9 (19.1%)	.444
Complex	40 (13.5%)	4 (8.5%)	.344
Medial Meniscus Tear Treatment			
Meniscectomy	38 (12.8%)	6 (12.8%)	.996
Repair	251 (84.5%)	40 (85.1%)	.916
Observation	8 (2.7%)	1 (2.1%)	.821
Lateral Meniscus Tear Location			
Anterior Horn	21 (4.8%)	1 (1.0%)	.081
Body	64 (14.5%)	7 (6.7%)	**.038**
Posterior Horn	248 (56.2%)	73 (71.6%)	**.004**
Posterior Horn-Body	35 (7.9%)	7 (6.7%)	.710
Root	54 (12.2%)	6 (5.9%)	.064
Meniscocapsular	2 (0.5%)	1 (1.0%)	.466
Bucket Handle	17 (3.9%)	7 (6.7%)	.186
Lateral Meniscus Tear Pattern			
Vertical-Longitundinal	155 (35.1%)	54 (52.9%)	**<.001**
Horizontal	24 (5.4%)	7 (6.7%)	.515
Oblique	17 (3.9%)	4 (3.9%)	.978
Radial	124 (28.1%)	12 (11.8%)	**<.001**
Undersurface	18 (4.1%)	7 (6.7%)	.229
Bucket Handle	17 (3.9%)	7 (6.7%)	.186
Complex	76 (17.2%)	7 (6.7%)	**.009**
Discoid	6 (1.4%)	1 (1.0%)	.757
Lateral Meniscus Tear Treatment			
Meniscectomy	145 (32.8%)	18 (17.6%)	**.002**
Repair	264 (59.9%)	65 (63.7%)	.358
Observation	32 (7.3%)	19 (18.6%)	**.001**

[a] = 6 patients with multiple, distinct medial meniscus tears; [b] = 32 patients with multiple, distinct lateral meniscus tears

Chondral Injury

	Skeletally Mature	Skeletally Immature	p-value
n (%)	218	21	
Chondral Injury			
Medial Compartment[a]	133 (61.0%)	12 (57.1%)	.729
Lateral Compartment[b]	65 (29.8%)	6 (28.6%)	.905
Patellofemoral Compartment[c]	20 (9.2%)	3 (14.3%)	.448
Medial Compartment			
Low Grade (1/2)	106 (79.7%)	11 (91.7%)	.320
Medial Femoral Condyle			
MFC 1	40 (30.1%)	5 (41.7%)	.508
MFC 2	55 (41.4%)	6 (50%)	.707
MFC 3	18 (13.5%)	1 (8.3%)	.555
MFC 4	6 (4.5%)	0 (0.0%)	.436
Medial Tibial Plateau			
MTP 1	6 (4.5%)	0 (0.0%)	.436
MTP 2	5 (3.8%)	0 (0.0%)	.478
MTP 3	3 (2.3%)	0 (0.0%)	.586
MTP 4	0 (0.0%)	0 (0.0%)	---[d]
Lateral Compartment			
Low Grade (1/2)	51 (78.5%)	1 (16.7%)	**.017**
Lateral Femoral Condyle			
LFC 1	12 (18.5%)	0 (0.0%)	.472
LFC 2	21 (32.3%)	1 (16.7%)	.641
LFC 3	8 (12.3%)	3 (50.0%)	**.040**
LFC 4	2 (3.1%)	1 (16.7%)	.237
Lateral Tibial Plateau			
LTP 1	6 (9.2%)	0 (0.0%)	.432
LTP 2	12 (18.5%)	0 (0.0%)	.572
LTP 3	4 (6.2%)	1 (16.7%)	.368
LTP 4	0 (0.0%)	0 (0.0%)	---[d]
Patellofemoral Compartment			
Low Grade (1/2)	15 (75%.0%	2 (66.6%)	.404
Trochlear Groove			
TG 1	0 (0.0%)	1 (33.3%)	.150
TG 2	0 (0.0%)	0 (0.0%)	---[d]
TG 3	0 (0.0%)	0 (0.0%)	---[d]
TG 4	1 (5.0%)	0 (0.0%)	.666
Patella			
P 1	6 (30.0%)	1 (33.3%)	.948
P 2	9 (45.0%)	0 (0.0%)	.218
P 3	3 (15.0%)	1 (33.3%)	.464
P 4	1 (5.0%)	0 (0.0%)	.666

[a] = 14 identified bipolar lesions within the medial compartment; [b] = 12 identified bipolar lesions within the lateral comnpartment; [c] = 2 identified bipolar lesions within the patellofemoral compartment; [d] = unable to calculate due to the absence of data

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Results

- Age
  - Age was included in the best fit model for overall meniscal injury, MMT, LMT, and chondral injury; however, it was not a significant factor for these outcomes.
- **Sex**
  - Male sex significantly predicted greater incidence of meniscus injury (OR 0.59, 95% CI [0.43, 0.81], p = .001), specifically LMT (OR 0.61, 95% CI [0.46, 0.82], p < .001). Male sex was also evaluated in the best fit models of MMT and chondral injury but was not a significant factor.
- **Body-Mass Index**
  - BMI was a significant predictor of medial compartment injury, both meniscal (OR 1.04, 95% CI [1.01, 1.06], p = .002) and chondral (OR 1.05, 95% CI [1.02, 1.09], p < .001). BMI was also evaluated in the best fit model for overall meniscal injury but was not a significant predictor. BMI was discarded from the best fit model for LMT for insignificance as a predictor.
- **Mechanism of Injury**
  - Mechanism of injury was not found to be a significant predictor of concurrent intra-articular injury.
- **Skeletal Maturity**
  - Skeletal maturity was statistically significant in all best fit models. SM was predictive of overall meniscal injury (OR 0.01, 95% CI [0.00, 0.16], p = .003), MMT (OR 0.00, 95% CI [0.00, 0.06], p =.002), LMT (OR 0.03, 95% CI [0.00, 0.75], p =.034), and chondral injury (OR 0.00, 95% CI [0.00, 0.49], p = .049).

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Results

- **Age::Skeletal Maturity**
  - The relationship between age and skeletal maturity is well-defined; thus, an interaction term was incorporated in the regression analysis. Age::Skeletal Maturity was included in all final best fit models; however, it was only significantly predictive in overall meniscal injury (OR 1.36, 95% CI [1.09, 1.71], p = .008) and MMT (OR 1.54, 95% CI [1.15, 2.11], p = .005).
- **Age::Body-Mass Index**
  - The relationship between age and BMI is well-defined; thus, an interaction term was added to the regression analysis. Age::BMI was not found to be a significant predictor of intra-articular injury and was discarded from all models.
- **Body-Mass Index::Skeletal Maturity**
  - The relationship between BMI and skeletal maturity is not well-defined. However, as adolescents continue to grow, increased mass may affect injury patterns; therefore, an interaction term was added to the regression analysis. BMI::Skeletal Maturity was included in the best fit model for chondral injury but was not found to be a significant predictor.
- **Sex::Skeletal Maturity**
  - The relationship between sex and skeletal maturity is well-defined; thus, an interaction term was added to the regression analysis. Sex::Skeletal Maturity was a significant predictor of MMT (OR 5.10, 95% CI [2.02, 12.10], p < .001), where skeletally immature female patients conferred increased risk of medial meniscus tear.

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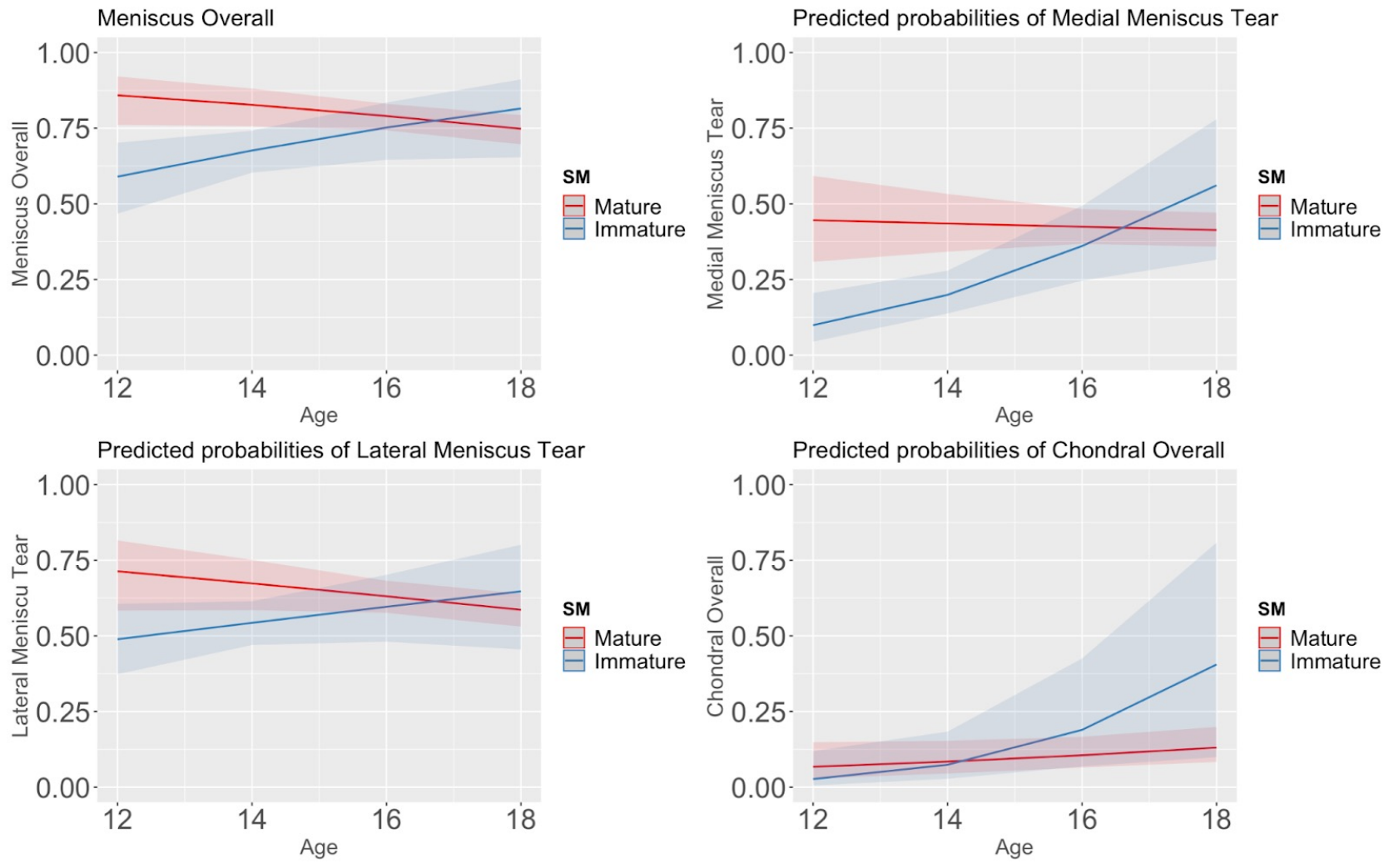
Results



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Results

Predictors of Intra-articular Pathology

	Meniscus Tear		Medial Meniscus Tear		Lateral Meniscus Tear		Chondral Injury	
Characteristic	Odds Ratio [95% CI]	p-value	Odds Ratio [95% CI]	p-value	Odds Ratio [95% CI]	p-value	Odds Ratio [95% CI]	p-value
Age	0.89 [0.79, 1.00]	.050	0.98 [0.88, 1.09]	.700	0.91 [0.82, 1.01]	.086	1.13 [0.99, 1.30]	.080
Sex	0.59 [0.43, 0.81]	**.001**	0.74 [0.54, 1.02]	.066	0.61 [0.46, 0.82]	**<.001**	0.75 [0.52, 1.09]	.140
Body Mass Index (kg/m^2)	1.02 [1.00, 1.05]	.012	1.04 [1.01, 1.06]	**.002**	---[a]	---[a]	1.05 [1.02, 1.09]	**< .001**
Mechanism of Injury	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]
Skeletal Maturity	0.01 [0.00, 0.16]	**.003**	0.00 [0.00, 0.06]	**.002**	0.03 [0.00, 0.75]	**.034**	0.00 [0.00, 0.49]	**.049**
Age::Skeletal Maturity	1.36 [1.09, 1.71]	**.008**	1.54 [1.15, 2.11]	**.005**	1.22 [0.99, 1.52]	.060	1.51 [0.96, 2.54]	.093
Age::BMI	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]
BMI::Skeletal Maturity	---[a]	---[a]	---[a]	---[a]	---[a]	---[a]	1.08 [0.99, 1.19]	.083
Sex::Skeletal Maturity	---[a]	---[a]	5.10 [2.02, 13.10]	**< .001**	---[a]	---[a]	---[a]	---[a]

[a] = variable removed from best fit predictive model by stewise procedure; :: = interaction variable; **bold** = significant variable in the model

Results

- There was a greater rate of meniscal intervention in skeletally mature patients
- Skeletally mature patients were more likely to undergo meniscectomy
- Skeletally immature patient were more likely to undergo observation

Results

Surgical Intervention for Concomitant Injury			
	Skeletally Mature	Skeletally Immature	p-value
Meniscal Treatment			
Meniscectomy	183 (24.8%)	24 (16.1%)	**.022**
Repair	515 (69.8%)	105 (70.5%)	.867
Observation	40 (5.4%)	20 (13.4%)	**< .001**
Chondral Treatment			
Microfracture	14 (6.4%)	0 (0.0%)	.619
Chondroplasty	14 (6.4%)	3 (14.3%)	.180
Graft	2 (0.9%)	0 (0.0%)	1.000
Observation	188 (86.2%)	18 (85.7%)	.945
All Interventions	728 (76.2%)	132 (77.6%)	.672
Meniscal Intervention	698 (94.6%)	129 (86.5%)	**< .001**
Chondral Intervention	30 (13.8%)	3 (14.3%)	.947

Conclusion

- Differences in meniscal tear patterns and locations and chondral pathology occur at increased rates dependent upon skeletal maturity
- Posterior horn injuries were more common among SI patients, with an increased rate of vertical-longitudinal morphology, as compared to SM patients where lateral meniscus tears more frequently involved the meniscal body with propensity for radial and complex morphologies.
- Observations may be likely based upon biomechanical changes during development

Conclusion

- There was a propensity towards partial menisectomy in skeletally mature patients.
- Male sex predicted meniscal injury, and BMI conferred increased medial compartment pathology.
- Skeletal maturity significantly predicted concomitant intra-articular injury associated with ACL rupture in pediatric and adolescent cohorts, emphasizing the impact of early or delayed physeal closure on increased risk of intra-articular injury.

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