North Carolina Orthopaedic Association

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Kiawah Island, South Carolina

This continuing medical education activity is jointly provided by the NCOA and the Southern Regional Area Health Education Center

Evaluating the Effect of an Off-the-Shelf Hip Orthosis on Balance in Post-operative Hip Arthroscopy: A Pilot Study

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Wake Forest School of Medicine

Disclosure

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  - Boards/Committees: AOSSM, ISHA, AANA
- All other authors report no declarations of interest
- This study was partially supported through a research grant from Bauerfeind, AG.

Background

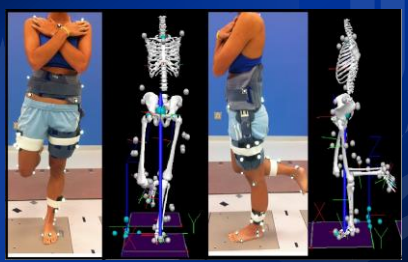
- Hip orthoses commonly utilized in post-op rehab
- Primary functions
  - Restrict range of motion
  - Protect compromised tissue
  - Role in balance?
- Limitations in literature
  - Variations in post-op rehab protocols
  - Lack of randomized control trials
  - Expert opinion

Methods

- Patient Selection
  - Wake Forest Baptist Medical Center
  - Hip arthroscopy for pathology associated with FAI
- Data Collection
  - WFU Human Performance and Biodynamics Laboratory
  - Four weeks post-operative appointment
- Off-The-Shelf Hip Orthosis
  - Sof-Tec Coxa®, Bauerfeind AG, Zeulenroda, Germany

Methods

- Barefoot static single leg postural sway test on force plate for 60 second trials

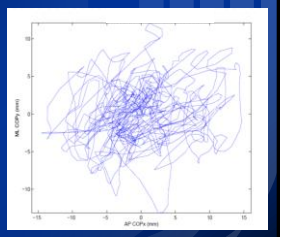


Methods

- Initial testing side and bracing status randomized
- Unbraced trials
  - Alternated between legs
  - Separated by at least one minute of rest
- Braced trials
  - Limited to one leg
  - Separated by at least two minutes of rest
- Three valid trials recorded for each condition *or* until six unsuccessful attempts per condition
- Two best trials included in final data analysis

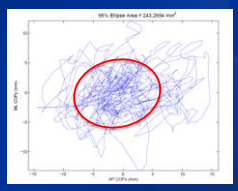
Methods

- MatLAB® Software
  - Mathworks, Natick, MA
- Center of pressure trajectory
  - Ground reaction forces
    - F_X, F_Y, F_Z
  - Ground reaction moments
    - M_X, M_Y, M_Z
- Stabilograms



Methods

- Center of Pressure Ellipse Area (COPEA)
  - Ellipse encircling 95% of the data points
  - Anterior-posterior and medial-lateral motion



Increases in COPEA = Decreased balance

Results: Demographics

	IMPROVED (N=10)	WORSENED (N=7)	P
Sex	9F / 1M	7F / 0M	
Age (yrs)	25.27 ± 5.61	28.29 ± 7.11	0.17
Height (m)	1.66 ± 0.05	1.68 ± 0.04	0.27
Weight (kg)	68.35 ± 15.23	64.04 ± 4.57	0.24
BMI (kg/m^2)	24.66 ± 4.99	22.75 ± 2.03	0.18

Data presented as mean ± SD

Results: Braced vs. Unbraced

- Patients improved by average 16% (82.25 mm^2)
- Patients worsened by average 18% (110.29mm^2)

	IMPROVED (N= 10)	WORSENED (N = 7)
Braced COPEA (mm^2)	426.64 ± 22.71	616.06 ± 75.89
Unbraced COPEA (mm^2)	508.89 ± 31.95	505.77 ± 28.18
P	0.002	0.04

Data presented as mean ± SD

Results: Pre-Op Physical Exam

- No differences between improved vs. worsened patients

	IMPROVED (N=10)	WORSENED (N=7)	P
Pain Duration (mo)	16.50 ± 11.11	10.71 ± 5.35	0.22
Hip Flexion (deg)	91.70 ± 13.33	91.43 ± 16.14	0.49
Hip Internal Rotation (deg)	6.50 ± 5.80	10.00 ± 5.77	0.12

Data presented as mean ± SD

Results: Pre-Op Radiographic Indices

- No differences between improved vs. worsened patients

	IMPROVED (N=10)	WORSENED (N=7)	P
Center Edge Angle	35.70 ± 4.83	29.29 ± 9.55	0.08
Lateral Center Edge Angle	28.40 ± 5.30	28.43 ± 5.32	0.50
Acetabular Index	38.80 ± 6.56	42.71 ± 3.35	0.08

Data presented as mean ± SD

Results: Intra-Op Findings

- No differences between improved vs. worsened patients

	IMPROVED (N=10)	WORSENED (N=7)	P
CSI Acetabulum	361.65 ± 236.52	201.14 ± 65.19	0.06
CSI Femoral Head	163.55 ± 146.75	172.00 ± 289.32	0.47
CSI Total	525.20 ± 377.89	373.14 ±289.70	0.19
IP Release (Y/N)	7 / 3	6 / 1	

Data presented as mean ± SD

Conclusions

- Some patients benefit from off-the-shelf bracing in the form of balance control
- Certain patients benefit from the protective range of motion function of the brace early on in the rehab cycle, but should come out of the brace when achieving independent ambulation
- Future research needed to define the role of a custom (vs off-the-shelf) hip orthosis for the group that did not show benefit at four weeks after surgery

Literature Cited

- Crossley, K. M., Zhang, W. J., Schache, A. G., Bryant, A. & Cowan, S. M. Performance on the single-leg squat task indicates hip abductor muscle function. *Am J Sports Med* **39**(4): 866-873, 2011.
- Kivlan, B. R. & Martin, R. L. Functional performance testing of the hip in athletes: a systematic review for reliability and validity. *Int J Sports Phys Ther* **7**(4): 402-412, 2012.
- Terry, K. *et al.* Cross-correlations of center of mass and center of pressure displacements reveal multiple balance strategies in response to sinusoidal platform perturbations. *J biomechanics* **44**(11): 2066-2076, 2011.
- Oliveira, L. F., Simpson, D. M. & Nadal, J. Calculation of area of stabilometric signals using principal component analysis. *Physiol Meas* **17**(4): 305-312, 1996.
- Tanaka ML, Stubbs AJ, Holst DC, Long BL. Evaluating cyclic pelvic movement in patients with acetabular labral tears: a case-controlled pilot study. *J Musculoskeletal Res* 17(3), 2014.
- Nicholls, RA. Intra-articular disorders of the hip in athletes. Physical Therapy in Sport. 2004; 5: 17-25
- Enseki, KR, Martin, RL, Kelly, BT. Rehabilitation after arthroscopic decompression of femoroacetabular impingement. Clinics in Sports Medicine. 2010; 29:247-255.
- Stalzer, S, Wahoff, M, Scanlan, M. Rehabilitation following hip arthroscopy. Clinics in Sports Medicine. 2006; 25: 337-357.

Questions

Risk Factors for Infection following Knee Arthroscopy: Analysis of a Large U.S. Cohort

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UNC HEALTH CARE ORTHOPAEDICS

North Carolina Orthopaedic Association

Annual Meeting – Kiawah Island, SC
Nov 2015

Background

- Knee arthroscopy is extremely common
- Infections rare
  - Cited as low as 0.04%
  - But potentially devastating
- Risk factors for infection unknown
  - Historically difficult to study due low incidence

Goal

To identify risk factors for infection following knee arthroscopy

Methods

- An administrative healthcare database was used
  - Pearldiver, Fort Wayne, IN, USA
  - Complete records from a large private insurer
  - 5% Medicare sample
- Patients identified by CPT code
  - 20 codes representing knee arthroscopy procedures

Methods

- Patients identified by CPT codes
  - 20 codes representing knee arthroscopy procedures
  - Closed procedures considered low-risk (13)
    - e.g. synovectomy, chondroplasty, microfracture
  - Partially open procedures considered high-risk (7)
    - e.g. mosaicplasty or ACL/PCL

Methods

- Infections developed within 90 days
- Deep infections
  - CPT code for I&D
- Superficial infections
  - ICD-9 infection code without CPT for I&D

Methods

- Infected vs. non-infected patients compared by:
  - Age
  - Sex
  - Diabetes
  - Overweight/obesity
  - Tobacco use
  - Comorbidities (using Charlson Index)
  - High-risk vs. low-risk procedures

Results

- 433,423 patients underwent 501,691 knee scopes
- Deep infection rate 0.20%
- Superficial infection rate 0.26%

Results

	Deep Infections	
	Relative Risk	95% CI
High-risk procedures	**2.27**	**(1.98-2.60)**

Results

Charlson Comorbidity Index		
	Median (IQR)	Compared to "No Infection"
No Infection	2 (0,3)	-
Deep Infection	1 (0,2)	P = 0.074
Superficial Infection	1 (0,3)	**P < 0.001**
All Infections	1 (0,2)	**P < 0.001**

Conclusion

- Largest risk factor = "high risk" procedure (RR 2.27)
- Other risks: male sex, tobacco user, diabetes, morbid obesity, CCI, and age under 50 years
  - Age likely confounded by procedure risk
- Helpful for pre-op counseling
- May aid in patient selection
- Can facilitate infection prevention efforts by targeting high-risk patients

Thank You

Appendices

(Manuscript Tables)

Appendix I

Table 1. CPT Codes for Arthroscopic Knee Index Surgeries

Code	Procedure includes:	Number of Procedures including code (atleast once)	Rate (of Arthroscopies)	Relative risk of infection
29866	Mosaicplasty with Autograft	1,048	0.21%	High
29867	Mosaicplasty with Allograft	935	0.19%	High
29868	Meniscal Transplantation	310-319	0.06%	High
29870	Synovial Biopsy	9,477	1.89%	Low
29873	Lateral Release	23,430	4.67%	Low
29874	Removal of Loose Body	22,905	4.57%	Low
29875	Limited Synovectomy	59,269	11.81%	Low
29876	Major Synovectomy	50,191	10.00%	Low
29877	Chondroplasty	154,158	30.73%	Low
29879	Abrasion Arthroplasty (Chondroplasty +/- Microfracture)	53,545	10.67%	Low
29880	Meniscectomy, Med and Lat	117,660	23.45%	Low
29881	Meniscectomy, Med or Lat	294,637	58.73%	Low
29882	Meniscal Repair, Med or Lat	18,554	3.70%	High
29883	Meniscal Repair, Med and Lat	1,968	0.39%	High
29884	Lysis of Adhesions	5,381	1.07%	Low
29885	Drilling & Grafting for OCD	535	0.11%	Low
29886	Drilling for OCD	1,321	0.26%	Low
29887	Drilling for OCD with Internal Fixation	1,376	0.27%	Low
29888	ACL Reconstruction	69,428	13.84%	High
29889	PCL Reconstruction	1,172	0.23%	High

Appendix II

Table 2. Infection Codes

CPT Codes for Knee Incision & Drainage Procedures	
Code	Description
29871	Arthroscopic Knee I&D
27310	Open Knee Arthrotomy
10180	Complex and/or Postoperative I&D
ICD-9 Codes for Postoperative infection	
Code	Description
711.0	Septic Arthritis
998.51	Postoperative Seroma
998.59	Other Postoperative Infection
999.3	Other Infection due to Medical Care

Appendix III

Table 3. Comorbidity Codes

Diabetes	
Codes (ICD-9)	Description
250.00 - 250.93	Multiple Diabetic Diagnoses
Overweight/Obesity	
Codes (ICD-9)	Description
278.02	Overweight
V85.21 - V85.25	BMI 25-30 (Overweight)
278.00	Obesity Not otherwise Specified
259.9	Obesity of endocrine origin
V85.30 - V85.39	BMI 30-40 (Obese)
278.01	Morbid Obesity
V85.41 - V85.45	BMI 40+ (Morbidly Obese)
Tobacco Use	
Codes	Description
305.1	ICD-9 Code for tobacco use disorder
V15.82	ICD-9 Code for history of tobacco use
99406 99407 99411 99412	CPT Codes for smoking cessation counseling

Appendix IV

Table 4. Arthroscopic Knee Procedures and I&D's (2005-2012)

Number of Patients undergoing arthroscopy	433,423
Number of Arthroscopic Procedures	501,691
Number of arthroscopic codes used	1,682,466
Average number of arthroscopic codes per procedure	3.35
Number undergoing I&D's within 90 days	1001
Rate	0.20%
Number of infections within 90 days not requiring I&D	1310
Rate	0.26%
Total number of infections within 90 days	2311
Rate	0.46%

Appendix V

Table 5. Post-Arthroscopic Knee Infections by Age and Sex (2005-2012)

		Number of Arthroscopies	Deep Infection[1]	Rate	P-Value	Relative Risk	95% CI	Superficial Infection[2]	Rate	P-Value	Relative Risk	95% CI	All Infections	Rate	P-Value	Relative Risk	95% CI
Age Group (in years)[3]	<1	16	0	0%				0	0%				0	0%			
	1	1-10*	0	0%				0	0%				0	0%			
	2-4	60	0	0%				1-10*	≤25.00%				1-10*	≤25.00%			
	5-9	339	1-10*	≤2.95%				1-10*	≤2.95%				2-20*	0.59-5.90%			
	10-14	9,724	20	0.21%				27	0.28%				47	0.48%			
	15-19	38,112	89	0.23%	<0.001	1.38-1.43*	(1.21-1.63)	106	0.28%	<0.001	1.38-1.41*	(1.24-1.57)	215	0.56%	<0.001	1.38-1.43*	(1.27-1.56)
	20-24	21,212	50	0.24%				71	0.33%				121	0.57%			
	25-29	21,314	45	0.21%				74	0.35%				119	0.56%			
	30-34	26,681	61	0.23%				101	0.38%				162	0.61%			
	35-39	37,038	106	0.29%				126	0.34%				232	0.63%			
	40-44	47,427	97	0.20%				137	0.29%				234	0.49%			
	45-49	59,568	137	0.23%				151	0.25%				288	0.48%			
	50-54	67,381	130	0.19%				155	0.23%				285	0.42%			
	55-59	61,594	106	0.17%				139	0.23%				245	0.40%			
	60-64	44,956	74	0.16%				115	0.26%				189	0.42%			
	65-69	20,490	12	0.06%	-	-	-	38	0.19%	-	-	-	50	0.24%	-	-	-
	70-74	11,799	24	0.17%				27	0.20%				51	0.37%			
	75-79	8,263	14	0.19%				20	0.24%				34	0.43%			
	80-84	3,691	1-5*	≤0.14%				1-3*	≤0.08%				1-8*	≤0.22%			
	85 +	1,282	1-5*	≤0.39%				1-3*	≤0.23%				1-8*	≤0.62%			
Sex	Female	237,048	355	0.15%				590	0.25%				945	0.40%			
	Male	257,751	646	0.25%	<0.001	1.67	(1.47-1.90)	723	0.28%	0.031	1.13	(1.01-1.26)	1,369	0.53%	<0.001	1.33	(1.23-1.43)
Comorbidities[4]	No Known Diabetes	487,321	844	0.17%				1,133	0.23%				1,977	0.41%			
	Diabetes	14,270	157	0.20%	<0.001	1.53	(1.29-1.82)	177	0.23%	0.002	1.29	(1.10-1.52)	333	0.42%	<0.001	1.39	(1.24-1.56)
	No Known Obesity/Overweight	454,877	899	0.20%				1,196	0.25%				2,095	0.45%			
	Overweight	2,353	3-15*	0.09-0.43%	0.003-0.862*	0.43-2.38*	(0.11-4.30)	8	0.34%	0.338	1.36	(0.68-2.71)	10-18*	0.42-0.81%	0.039-0.884*	0.95-1.80*	(0.51-2.83)
	Obese	25,990	38-47*	0.14-0.18%	0.072-0.572*	0.74-0.92*	(0.54-1.23)	83	0.32%	0.033	1.27	(1.02-1.59)	121-130*	0.47-0.50%	0.218-0.573*	1.04-1.12*	(0.87-1.33)
	Morbidly Obese	16,472	51	0.31%	0.001	1.67	(1.19-2.35)	73	0.44%	<0.001	1.77	(1.40-2.24)	124	0.75%	<0.001	1.68	(1.40-2.01)
	No Known tobacco use	462,345	876	0.19%				1,160	0.25%				2,036	0.44%			
	Known tobacco use	29,456	125	0.42%	<0.001	1.68	(1.39-2.03)	170	0.58%	<0.001	1.76	(1.50-2.06)	295	0.75%	<0.001	1.72	(1.53-1.95)
Risk/Invasiveness of Arthroscopic Procedure	Low	469,569	774	0.16%				1,022	0.22%				1,798	0.37%			
	High	32,458	285	0.88%	<0.001	2.27	(1.98-2.60)	363	0.46%	<0.001	2.13	(1.90-2.40)	668	0.83%	<0.001	2.19	(2.00-2.39)

[1] Deep infections defined as presence of a CPT code for I&D within 90 days of knee arthroscopy

[2] Superficial infection defined as presence of an ICD-9 code for post-operative infection within 90 days of knee arthroscopy without I&D

[3] Data on patients <65 years old obtained from United Healthcare data, data on those 65+ years old obtained from Medicare data

[4] Diabetes, obesity and smoking determined by presence of ICD-9 and CPT codes for these conditions

* Age calculations compare patients <50 versus 50+ years old

** Patient populations containing two or less members are not available as precise numbers but only as ranges based on data sharing agreements to protect patient privacy. In these cases, results, P-values and relative risks are presented as the range of possible values.

Appendix V (abridged)

Table 5. Post-Arthroscopic Knee Infections by Age and Sex (2005-2012)

	Deep Infections			Superficial Infections			Total Infections		
	P-Value	Relative Risk	95% CI	P-Value	Relative Risk	95% CI	P-Value	Relative Risk	95% CI
High-risk procedures	**<0.001**	**2.27**	**(1.98-2.60)**	**<0.001**	**2.13**	**(1.90-2.40)**	**<0.001**	**2.19**	**(2.00-2.39)**
Known tobacco use	**<0.001**	**1.68**	**(1.39-2.03)**	**<0.001**	**1.76**	**(1.50-2.06)**	**<0.001**	**1.72**	**(1.53-1.95)**
Sex (Male vs. Female)	**<0.001**	**1.67**	**(1.47-1.90)**	**0.031**	**1.13**	**(1.01-1.26)**	**<0.001**	**1.33**	**(1.23-1.45)**
Overweight	0.003-0.863	0.43-2.38	(0.11-4.30)	0.388	1.36	(0.68-2.71)	0.009-0.884	0.95-1.80	(0.51-2.83)
Obese	0.072-0.572	0.74-0.92	(0.54-1.23)	**0.033**	**1.27**	**(1.02-1.59)**	0.218-0.673	1.04-1.12	(0.87-1.33)
Morbidly Obese	**0.001**	**1.57**	**(1.19-2.09)**	**<0.001**	**1.77**	**(1.40-2.24)**	**<0.001**	**1.68**	**(1.40-2.01)**
Diabetes	**<0.001**	**1.53**	**(1.29-1.82)**	**0.002**	**1.29**	**(1.10-1.51)**	**<0.001**	**1.39**	**(1.24-1.56)**
Age (<50 vs. >50 yrs)	**<0.001**	**1.38-1.43**	**(1.21-1.63)**	**<0.001**	**1.38-1.41**	**(1.24-1.57)**	**<0.001**	**1.38-1.43**	**(1.27-1.56)**

Appendix VI

Table 6. Charlson Comorbidity Index (CCI) by Infection Status

Infection Status	CCI Median (IQR)	P-Value (Compared to "No Infection")
No Infection	2 (0,3)	-
Infection Undergoing I&D	1 (0,2)	0.074[1]
Infection not Undergoing I&D	1 (0,3)	**<0.001**[2]
All Infections	1 (0,2)	**<0.001**[2]

[1]Trend toward patients with infections having higher CCI despite lower median because data distribution skewed with long upper tail

[2]Patients with infections have higher CCI despite lower median because data distribution skewed with long upper tail

No difference between infections undergoing or not undergoing I&D (P=0.968)

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October 10th, 2015

Randomized Prospective Study of Anesthetic Techniques in Unicondylar Knee Arthroplasty

Disclosures

- No conflicts of interest related to the material presented in this presentation.

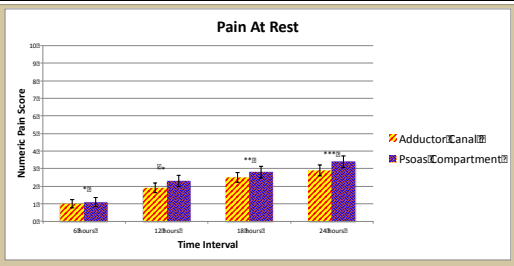
Study Details

- Prospective, randomized, double-blind equivalency trial
- Medial unicondylar knee arthroplasty
- 150 patients (147 analyzed)
  - 75 Psoas compartment block
  - 75 Adductor canal block
- All had posterior capsule injection
- Multimodal analgesics
  - Celecoxib, Acetaminophen, Pregabalin

Study Details

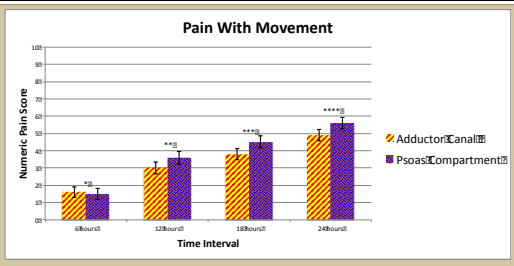
- Primary outcome:
  - Pain scores with rest and movement at 6 hours
    - Within 2 points on verbal pain scale (0-10 range)
- Secondary outcomes:
  - Pain scores at 12,18 & 24 hours (rest & movement)
  - Quadriceps strength (0-5 scale) @ 6 hours
  - Opioid consumption and opioid related side effects over 24 hour period

Rest Pain



Mean verbal pain scores (Numerical Rating Scale 0-10) at 6-, 12-, 18-, and 24-hours.
Error bars represent standard error of the mean.
*P < 0.0001, **P = 0.0001, ***P = 0.001;
P < 0.025 denotes equivalency at 6 hours; P < 0.05 denotes equivalence at 12,18 and 24 hours

Movement Pain



Mean verbal pain scores (Numerical Rating Scale 0-10) at 6-, 12-, 18-, and 24-hours.
Error bars represent standard error of the mean.
*P < 0.0001, **P = 0.0022, ***P = 0.0045, ****P = 0.0026
P < 0.025 denotes equivalency at 6 hours; P < 0.05 denotes equivalence at 12,18 and 24 hours

Quadriceps Strength

Table 4. Quadriceps motor strength

	Adductor Canal Block (*n*=74)		Psoas Compartment Block (*n*=73)		
	n	%	*n*	%	*P*-value
Straight leg raise (score)*					
5	29	39	8	11	<0.0001*
4	24	32	7	10	0.001*
3	13	18	21	29	0.12
2	6	8	18	25	0.008*
1	2	3	19	26	<0.0001*
(5 or 4)	53	72	15	21	<0.0001*
(3 or 2 or 1)	21	28	58	79	<0.0001*
	Mean	**SD**	**Median**	**Mean**	**SD**	**Median**	
Straight leg raise (score)	4.0	1.1	4.0	2.5	1.3	2	<0.0001*

Opioids and Side Effects

- No differences in:
  - Time to first analgesic.
  - Cumulative opioids consumed over 24 hours.
  - Incidence of nausea or vomiting at any time point.
  - Incidence of itching at 12,18 or 24 hours.
- Only difference found:
  - Higher incidence of itching at 6 hours in adductor canal group; (*p*=.046)

Conclusion

- Adductor canal blockade:
  - Equivalent analgesia to a psoas compartment block.
  - Significantly less quadriceps motor weakness.
  - Similar side effect profile, except for increased itching at 6 hours.
- Should be considered as an analgesic option for patients undergoing medial unicondylar arthroplasty.

MRI findings versus intra-operative pathology in hip arthroscopy

32nd Southern Orthopaedic Association Annual Meeting
Asheville, North Carolina
July 16, 2015

Duke Orthopaedic Surgery
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Disclosures

- None of the authors have any disclosures to report.

Source of Funding

- None of the authors received funding in the production of this research.

Introduction

- MRIs and MRAs are standard of care to evaluate intra-articular hip pathology
- Arthroscopy: gold standard to evaluate hip labral pathology
- MRI has been reported to accurately identify labral pathology in 91-95% of cases
- Determine accuracy of MRI compared to intra-operative labral and chondral pathology specifically in setting of hip dysplasia

Methods

- Retrospective review
- PI performed all surgeries
- Indications: CEA < 20, failed non-op mgmt X 6 months, mechanical symptoms
- Combined hip arthroscopy and periacetabular osteotomy (PAO) for treatment of intraarticular pathology and hip dysplasia
- January 1, 2013 to December 31, 2013

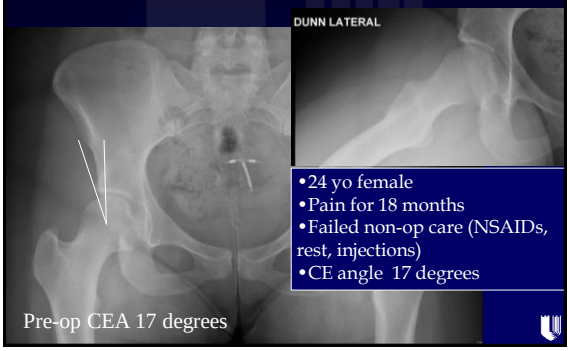
Methods

- 17 patients (19 hips)
  - 14 females: 3 males
  - 11 left hips: 8 right hips
- Average age at surgery 29.49 years (range, 17-42 years)
- Fellowship trained musculoskeletal radiologist blinded to intra-op findings reviewed 19 pre-op MRIs (taken avg 83 days before surgery)
  - MRI findings directly compared to operative note findings

Operative Procedure

- Supine on fracture table – arthroscopic perineal post
- Single prep and drape – for arthroscopy and PAO
- Hip arthroscopy followed by PAO
- Single surgeon performs both arthroscopy and PAO

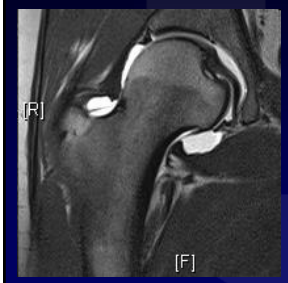
Case Example

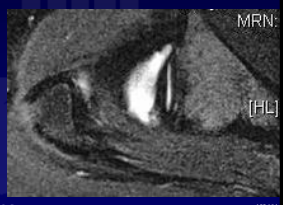


- 24 yo female
- Pain for 18 months
- Failed non-op care (NSAIDs, rest, injections)
- CE angle 17 degrees

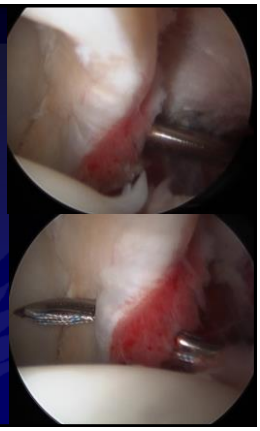
Pre-op CEA 17 degrees

Pre-operative MRI





- Labral tear
- Hypertrophied ligamentum teres



- Post-op CEA 32 degrees

Results

- Labrum
  - MRI correctly correlated to intraop pathology 18/19 (PPV = 94.7%) of hips
  - 1 of 19 (5.3%) hips MRI demonstrated labral tear when labrum was intact

Results

- Chondral lesions
  - Discrepancy between MRI and intra-operative findings in 9/19 (47.4%) of hips
    - MRI noted possible acetabular cartilage delamination vs softening in 4/19 (21.1%) of the hips when intact
    - 3/19 (15.8%) hips MRI showed cartilage delamination with full or partial thickness loss when cartilage was intact
    - 1/19 (5.3%) hips demonstrated questionable acetabular chondral loss when grade III/IV changes were noted in the acetabulum
    - 1/19 (5.3%) hips demonstrated no chondral defect when mild delamination was noted
  - MRI correlated with intraoperative findings in 10/19 (52.6%) hips
    - No chondral defect in the acetabulum in 1/19 (5.3%) of hips when no delamination

Results

- Ligamentum teres:
  - Discrepancy between MRI and intra-operative findings in 7/19 (36.8%) of hips
    - Frayed, degenerative or partial tear in the ligamentum teres in 5/19 (26.3%) of hips when no tear was noted (hypertrophied or normal)
    - Ligamentum teres rupture in 1/19 (5.3%) hip when a small tear was noted
    - Intact ligamentum teres in 1/19 (5.3%) of hips when hypertrophied
  - Intraoperative findings
    - Torn 4/19 (21.1%)
    - Hypertrophied 8/19 (42.1%)
  - Overall accuracy of diagnosis on MRI was found to be 63.2%

Overall Results

PPV – 56%

NPV – 33%

Sensitivity – 82%

Specificity – 12.5%

Accuracy – 52.6%

Limitations

- Retrospective
- Small cohort
- One MSK radiologist reviewing MRI
- Non-standardized MRI sequences
- Observation, time and selection bias

Conclusion

- MRI findings compared to intra-operative hip arthroscopy findings
  - Correlate with labral pathology in 94.7% of patients
  - Did not correlate as well for chondral (52.6%) or ligamentum teres (63.2%) pathology
  - Caution when using MRI to diagnose cartilaginous or ligamentum teres pathology
  - Consider having a MSK trained radiologist to review preoperative MRIs

References

- Chan YS, Lien LC, Hsu HL, et al. Evaluating hip labral tears using magnetic resonance arthrography: a prospective study comparing hip arthroscopy and magnetic resonance arthrography diagnosis. *Arthroscopy* 2005; 21:1250e1-7.
- Czerny C, Hofmann S, Urban M, et al. MR arthrography of the adult acetabular capsular-labral complex: correlation with surgery and anatomy. *AJR* 1999; 173:345–349.
- Mintz DN, Hooper T, Connell D, et al. Magnetic Resonance Imaging of the Hip: Detection of Labral and Chondral Abnormalities Using Noncontrast Imaging. *Arthroscopy* 2005; 21(4):385-393.
- Ziegert AJ, Blankenbaker DG, De Smet AA, et al. Comparison of the Standard Hip MR Arthrographic Imaging Planes and Sequences for Detection of Arthroscopically Proven Labral Tear. *AJR* 2009; 192:1397-1400.
- Zlatkin MB, Pevsner d, Sanders TG, et al. Acetabular Labral Tears and Cartilage Lesions of the Hip: Indirect MR Arthrographic Correlation With Arthroscopy – A Preliminary Study. *AJR* 2010; 194:709-714.

Thank You!

Advantages to Non-arthrographic MRI

- Noninvasive
- Free of radiation and gadolinium exposure
- Least resource intensive and thus less costly
- Logistically easier to coordinate compared to d-MRA and i-MRA

HASH MRI Protocol

- Cor T1
- Obl Ax fs pd
- Cor fs pd
- Sag fs pd
- Axial VIBE sequence: allows for reformatting
- Ax haste (pd-proton density)

Prevalence and Complications of Musculoskeletal Infections in Adolescents: A Result of Delay in Diagnosis?

Sarah N. Pierrie, MD
Carolinas Medical Center
October 10, 2015

Introduction to Musculoskeletal Infection

- Incidence is rising
- Can cause
  - Permanent impairment
  - Systemic disease

Diagnosis

- Gold standard: culture
- Diagnostic algorithms
  - WBC
  - ESR
  - Fever
  - Nonweightbearing
  - CRP

  } Kocher criteria
- Axial imaging (e.g. MRI)

Purpose

- To evaluate the prevalence and complications of MSK infections in older children and adolescents
- To determine whether the Kocher criteria are predictive of septic arthritis in older children and adolescents

Results

- Retrospective review
- 30 patients age 10-18 years

• Demographic data	• Lab data
• Historical information	• Microbiology data
• Vital signs	• Functional/clinical outcomes

- Septic hip cohort: 14 patients

Results

- Time to diagnosis 9.3 days (range 0-30 days)
- 83% had seen ≥1 provider **prior** to diagnosis
  - 44% had seen ≥2 providers **prior** to diagnosis
- Chief complaint
  - Focal pain 93%
  - Subjective fever 82%
  - Objective fever (temperature > 38C) 7%

Results

Laboratory values
- WBC 11,600
- ESR 50.6
- CRP 15.5

Cultures
- 68% OSSA
- 9% MRSA

Results

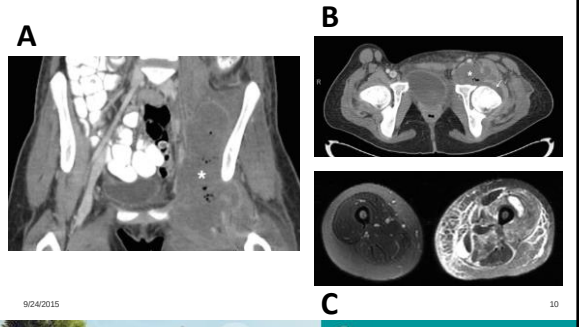
- Patients with…
  - 1 positive criterion: n = 7
  - 2 positive criteria: 6
  - 3 positive criteria: 1
  - 4 positive criteria: 0
- Most common positive finding: ESR
- Mean CRP: 16.8mg/L

Results: Complications

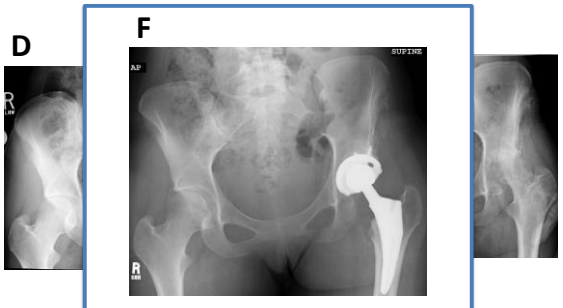
Systemic Complications	
Deep venous thrombosis	3
Pneumonia	2
Pulmonary embolism	1
Clostridium difficile infection	1
Wound infection	1

Musculoskeletal Complications	
Avascular necrosis	3
Persistent limp	3
End-stage arthrosis	2
Heterotopic ossification	2
Loss of terminal motion	2
Recurrent idiopathic effusion	1
Chronic osteomyelitis	1

Complications: AVN



Complications: AVN



Discussion

In teens and adolescents with MSK infection,
- There is a trend toward longer symptom duration before definitive treatment
- Kocher criteria are inconsistently present
- CRP is almost uniformly elevated
- MRI is an important diagnostic tool
- Complications occur in one third of patients

References

- Arnold SR, Elias D, Buckingham SC, et al. Changing patterns of acute hematogenous osteomyelitis and septic arthritis: emergence of community-associated methicillin-resistant Staphylococcus aureus. *J Pediatr Orthop*. 2006;26(6):703-708. doi:10.1097/01.bpo.0000242431.91489.b4.
- Haas A, Wenger DR. Continuing Problems in Septic Arthritis of the Hip: Analysis of Results and Current Treatment Recommendations. *Iowa Orthop J*. 1984.
- Kocher MS, Zurakowski D, Kasser JR. Differentiating Between Septic Arthritis and Transient Synovitis of the Hip in Children: An Evidence-Based Clinical Prediction Algorithm*†. *The Journal of Bone & Joint Surgery*. 1999.
- Kocher MS, Mandiga R, Zurakowski D. Validation of a clinical prediction rule for the differentiation between septic arthritis and transient synovitis of the hip in children. … *Journal of Bone & Joint* …. 2004.
- Levine MJ, McGuire KJ, McGowan KL, Flynn JM. Assessment of the test characteristics of C-reactive protein for septic arthritis in children. *J Pediatr Orthop*. 2003;23(3):373-377.
- Caird MS, Flynn JM, Leung YL, Millman JE, D'Italia JG, Dormans JP. Factors distinguishing septic arthritis from transient synovitis of the hip in children. A prospective study. *The Journal of Bone & Joint Surgery*. 2006;88(6):1251-1257. doi:10.2106/JBJS.E.00216.

References

- Rosenfeld S, Bernstein D, Daram S, Dawson J, Zhang W. Predicting the Presence of Adjacent Infections in Septic Arthritis in Children. *J Pediatr Orthop*. 2015:1. doi:10.1097/BPO.0000000000000389.
- Kocher MS, Zurakowski D, Kasser JR. Differentiating between septic arthritis and transient synovitis of the hip in children: an evidence-based clinical prediction algorithm. *The Journal of Bone & Joint Surgery*. 1999;81(12):1662-1670.
- Vander Have KL, Karmazyn B, Verma M, et al. Community-associated methicillin-resistant Staphylococcus aureus in acute musculoskeletal infection in children: a game changer. *J Pediatr Orthop*. 2009;29(8):927-931. doi:10.1097/BPO.0b013e3181bd1e0c.
- Miles F, Voss L, Segedin E, Anderson BJ. Review of Staphylococcus aureus infections requiring admission to a paediatric intensive care unit. *Arch Dis Child*. 2005;90(12):1274-1278. doi:10.1136/adc.2005.074229.
- McCarthy JJ, Dormans JP, Kozin SH, Pizzutillo PD. Musculoskeletal infections in children: basic treatment principles and recent advancements. *Instr Course Lect*. 2005;54:515-528.
- Mantadakis E, Plessa E, Vouloumanou EK, Michailidis L, Chatzimichael A, Falagas ME. Deep venous thrombosis in children with musculoskeletal infections: the clinical evidence. *Int J Infect Dis*. 2012;16(4):e236-e243. doi:10.1016/j.ijid.2011.12.012.

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The Utility of a Screening MRI for Pediatric Patients with Suspected Musculoskeletal Infection

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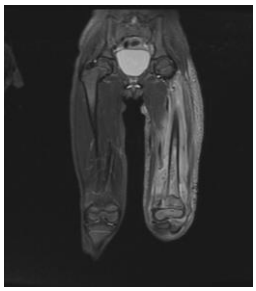
Franklin Gettys, MD,
Brian Scannell, MD
Steven Frick, MD
Nigel Rozario, BS
Kelly VanderHave, MD
Brian Brighton, MD, MPH

Background

- Septic Arthritis or Benign Process?
- Multifocal Musculoskeletal Infections
- Utility of MRI



Study Purpose

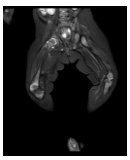
- Describe our imaging protocol
- Report on a cohort of patients who underwent a screening MRI for suspected musculoskeletal infection prior to any procedural intervention.
- Determine the clinical and/or laboratory values that are predictive of patients presenting with septic arthritis versus multifocal musculoskeletal infection

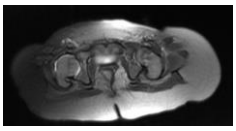
Methods

- Single institution retrospective review from 2008-2014
- Patients age <19 years
- Include all who underwent a screening MRI for a suspected musculoskeletal infection prior to intervention
  - A screening MRI was defined as an MRI that examined 1 joint and at least 1 continuous bony structure
- Exclusion criteria:
  - Incomplete medical records
  - Incomplete MRI images
  - MRI for non infectious work up

MRI Protocol

- Hip to toe
- SAG IR Lumbar
- COR IR, COR T1 Pelvis to Ankles
- AX T1, AX T2 FS
- Gadolinium per MD order or Rad request





Analysis

Patients were analyzed in 4 groups:

- no infection
- musculoskeletal infection
- septic arthritis of a joint without concomitant infection (SAJ)
- multifocal musculoskeletal infection (MMI)

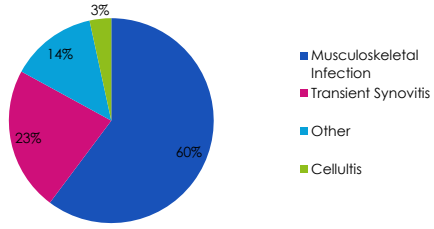
Analysis

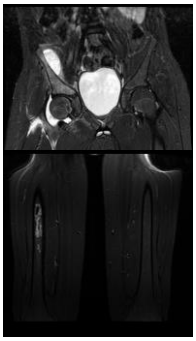
Independent Variables

- Age, gender
- Weight bearing status (WBS) at admission,
- White blood cell count (WBC), CRP (mg/dL), ESR, hemoglobin (HGB), temperature at admission.
- Number of positive Kocher criteria (temperature > 101.3 F°, ESR > 40 mm/hr, non weight bearing on affected side, WBC ≥ 12,000 cells/mm^3)

Results

Study Population n = 88





Results

- Musculoskeletal Infections
  - SAJ 19/53 (35.8%)
    - 13 hip, 4 knee, 1 ankle, 1 tarsal/metatarsal
  - MMI 13/53 (24.5%)
    - 12 septic arthritis of hip with
      - osteomyelitis (8),
      - pyomyositis (2)
      - abscess (1)
      - septic arthritis of knee, abscess, osteomyelitis, (1)
    - 1 septic arthritis of knee with osteomyelitis

Patients with Multifocal Musculoskeletal Infection (MMI) and their Subsequent Procedure

Patient	Procedure
Patient #1	I&D Hip, Abscess, Drilling Femoral Head
Patient #2	I&D Hip, Knee, Ankle, Foot
Patient #3	I&D Hip & Pelvis
Patient #4	I&D Hip & Drilling Ilium
Patient #5	I&D Hip & Bilateral Tibia Aspiration
Patient #6	Hip and Proximal Femur Aspiration
Patient #7	I&D Gluteus Maximus, Minimus, Iliac wing
Patient #8	I&D Hip
Patient #9	I&D Hip
Patient #10	I&D Hip
Patient #11	I&D Hip
Patient #12	I&D Hip
Patient #13	I&D Knee

Results

MMI vs. SAJ

- MMI older
  - 7 years MMI vs. 3.3 years SAJ (p=0.09)
- MMI higher CRP
  - 13.09(6.24-19.94) vs.. 4.52(2.83-6.2) p=0.01.
- MMI lower WBC count
  - 12.05(7.33-16.77) vs.. 13.77(12.08-15.45) p=0.02.
- No differences in age, ESR, number of Kocher criteria, and temperature on admission.

Results

Those with CRP of 9 were 9.7 times more likely to have MMI

- 14.7 times more likely with CRP of 13
- 22 times more likely with CRP of 15

Results

Musculoskeletal infection (MI) vs. No infection (NI)

- CRP
  - (NI) 3.7(1.57-5.83) vs. (MI) 9.66(7.21-12.1) p=<0.001
- ESR
  - (NI) 25.96(18.39-33.53) vs. (MI) 60.36(49.01-71.71) p=<0.001
- Temperature on admission
  - (NI) 98.86(98.06-99.66) vs. (MI) 99.63(99.14-100.13) p=0.02
- Number of Kocher criteria
  - (NI)1.14(0.85-1.43) vs. (MI)1.87(1.56-2.17) p=0.002

Study Limitations

- **Retrospective study that only included patients from an MRI database**

Conclusions

- **Screening MRI was useful in the diagnosis and management of patients presenting with musculoskeletal infection.**
- **Nearly 25% of our cohort of musculoskeletal infections had a multifocal musculoskeletal infection.**
- **The odds of having a multifocal musculoskeletal infection on MRI versus an isolated septic arthritis was 9.7 times higher with a CRP > 11, however no other clinical factors were significant in determining the presence of an associated bone or soft tissue infection on MRI.**
- **The use of MRI is recommended in the evaluation and management of children with musculoskeletal infections as clinical factors alone may not be adequate in determining the presence of multifocal infection.**
- **The early recognition of a multifocal infection allows one to make the appropriate diagnosis and provide proper surgical care at the initial operation.**

Treatment of Pelvic Chondroblastoma with Denosumab: The Role of RANK Signaling in Benign-Aggressive Tumors

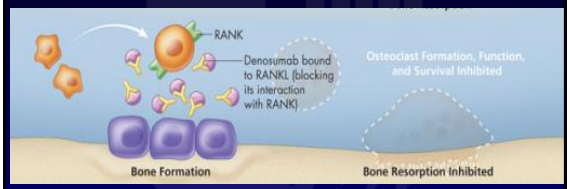
Mitchell Klement, MD,
Julia Visgauss, MD, Will Eward DVM, MD
NCOA Annual Meeting
Oct 10, 2015

Case Presentation

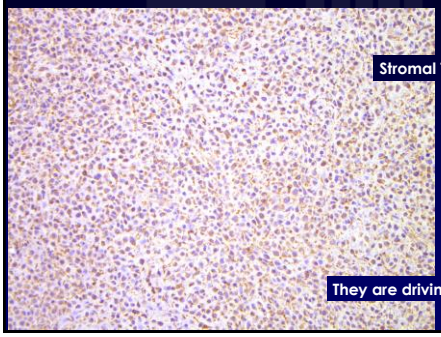
- 15 yoM with eight months of progressive, mechanical right hip pain
- PE: antalgic gait and tenderness to palpation over the right buttock and groin

Case Presentation

Rank-Rank L Signaling Pathway



In Benign Aggressive Tumors, who are the main cellular players?

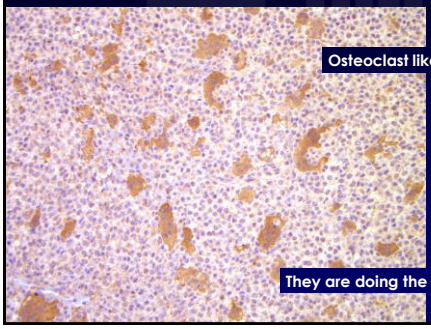


Stromal Tumor Cells

RANK-L +

They are driving the bus.

In Benign Aggressive Tumors, who are the main cellular players?



Osteoclast like Giant Cells

RANK receptor +

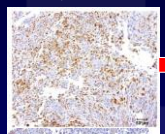
They are doing the dirty work.

Role of Denosumab in Benign Aggressive Tumors

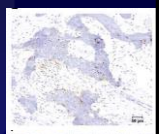
Denosumab Induces Tumor Reduction and Bone Formation in Patients with Giant-Cell Tumor of Bone

Daniel G. Branstetter, Scott D. Nelson, J. Carlos Manivel, et al. *Clin Cancer Res* 2012;18:4415-4424.

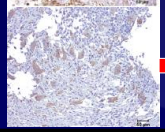
Pre-treatment: numerous RANK-L positive tumor stromal cells



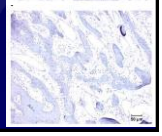
Post-treatment: minimal RANK-L positive tumor stromal cells



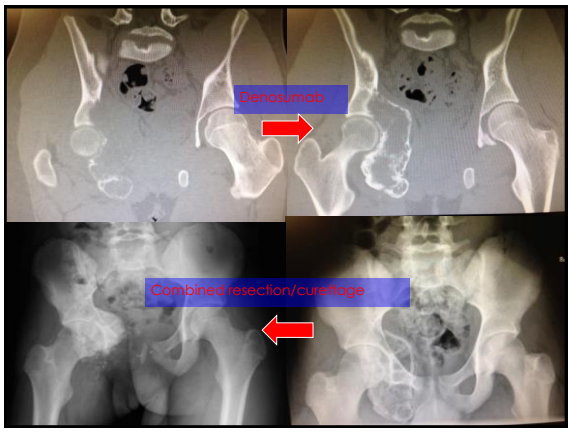
Pre-treatment: numerous RANK receptor positive tumor giant cells



Post-treatment: No RANK receptor positive tumor giant cells

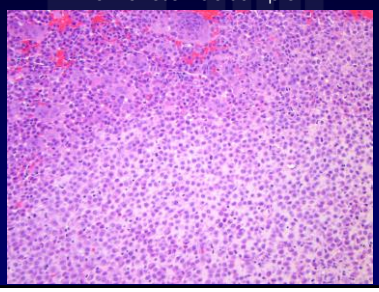


Back to Our Case Report



What is the effect of Denosumab on Chondroblastoma?

Pre-Denosumab Sample



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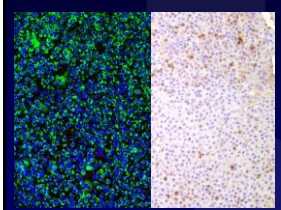
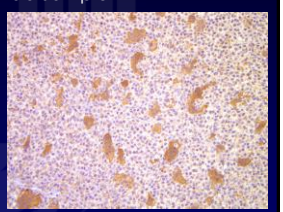


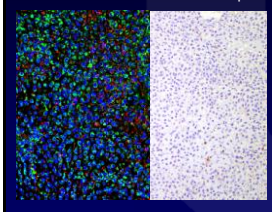
Immunofluorescence and Immunohistochemical staining of RANK-L



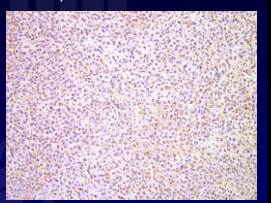
Immunohistochemical staining of RANK receptor

What is the effect of Denosumab on Chondroblastoma?

Post-Denpsumab Sample



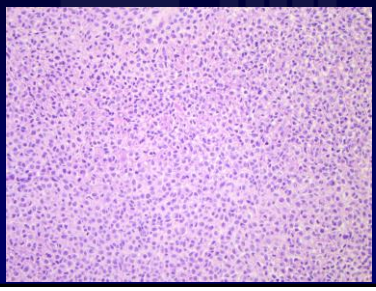
Immunofluorescence and Immunohistochemical staining of RANK-L



Immunohistochemical staining of RANK receptor

What is the effect of Denosumab on Chondroblastoma?

Post-Denpsumab Sample



What is the effect of Denosumab on Chondroblastoma?

- Treatment of Chondroblastoma with Denosumab results in abrogation of osteoclast-like giant cell formation with decrease in resultant osteolysis
- However, UNLIKE GCT, we don't see over-expression of RANK-L in the stromal cells of Chondroblastoma, and see little effect on neoplastic mononuclear cells following treatment with Denosumab.

Summary

- The RANK/RANK-L signaling pathway plays an important role in the osteolytic process of benign aggressive tumors such as GCT and Chondroblastoma.
- Indications, dosing, and duration of Denosumab treatment are still being investigated
- The success with Denosumab treatment in our patient are encouraging regarding the potential for improvements in treatment and management of patient's with osteolytic pathologic lesions beyond GCT of Bone
- However it's pathologic role in various tumors may be different, which may have implications on future management.

References

1. Lacey DL, Boyle WJ, Simonet WS, et al. Bench to bedside: elucidation of the OPG-RANK-RANKL pathway and the development of denosumab. Nature reviews Drug discovery 2012;11:401-19.
2. Won KY, Kalil RK, Kim YW, Park YK. RANK signalling in bone lesions with osteoclast-like giant cells. Pathology 2011;43:318-21.
3. Huang L, Cheng YY, Chow LT, Zheng MH, Kumta SM. Receptor activator of NF-kappaB ligand (RANKL) is expressed in chondroblastoma: possible involvement in osteoclastic giant cell recruitment. Molecular pathology : MP 2003;56:116-20.
4. Xu SF, Adams B, Yu XC, Xu M. Denosumab and giant cell tumour of bone-a review and future management considerations. Current oncology (Toronto, Ont) 2013;20:e442-7.
5. Prommer E. Palliative Oncology: Denosumab. The American journal of hospice & palliative care 2014.
6. Wang X, Yang KH, Wanyan P, Tian JH. Comparison of the efficacy and safety of denosumab versus bisphosphonates in breast cancer and bone metastases treatment: A meta-analysis of randomized controlled trials. Oncology letters 2014;7:1997-2002.
7. Mandema JW, Zheng J, Libanati C, Perez Ruixo JJ. Time course of bone mineral density changes with denosumab compared with other drugs in postmenopausal osteoporosis: a dose-response-based meta-analysis. The Journal of clinical endocrinology and metabolism 2014;99:3746-55.
8. Branstetter DG, Nelson SD, Manivel JC, et al. Denosumab induces tumor reduction and bone formation in patients with giant-cell tumor of bone. Clinical cancer research : an official journal of the American Association for Cancer Research 2012;18:4415-24.
9. Chawla S, Henshaw R, Seeger L, et al. Safety and efficacy of denosumab for adults and skeletally mature adolescents with giant cell tumour of bone: interim analysis of an open-label, parallel-group, phase 2 study. The Lancet Oncology 2013;14:901-8.
10. Agarwal A, Larsen BT, Buadu LD, et al. Denosumab chemotherapy for recurrent giant-cell tumor of bone: a case report of neoadjuvant use enabling complete surgical resection. Case reports in oncological medicine 2013;2013:496351.
11. http://www.cancer.gov/cancertopics/druginfo/fda-denosumab
12. http://www.accessdata.fda.gov/drugsatfda_docs/label/2013/125320s094lbl.pdf
13. http://www.healthplexus.net/article/bone-biology-and-role-rankranklopg-pathway

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DukeMedicine

Risk Factors For Disease Progression After Surgical Treatment of Extremity Metastatic Bone Disease

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Purpose / Hypothesis

one-year postoperative survival for metastatic skeletal disease has improved with better adjuvant therapies:

0.3% Wedin, R., et al 1999 → **36%** Ratasvuori et al 2013

We aimed to assess risk factors associated with:

- **radiographic disease progression**
- **surgical failure**
- **survival**

in "longer-term" (6+ month) survivors

Materials and Methods

Retrospective Review	surgical treatment of 89 metastatic bone lesions, extremity only treated between 2004-2014 by Duke Orthopaedic Oncology 6+ months of radiographic imaging
Variables Considered	lesion characteristics, surgical details, radiotherapy timing, antiresorptive medication use, Mirels score
Statistical Analysis	Fischer's Exact Test, t-test, Cox proportional-hazards models

1. **Radiographic Disease Progression**
   plain radiographs assessed at 3 month intervals
   Harada, H., et al. (2010) criteria
2. **Surgical Failure**
   hardware failure, infection
3. **Survival**

Interval Disease Progression & Implant Failure 18 months postop

Results

1. **Radiographic Disease Progression**
   - Gender (Female): HR 0.361, p<0.01
   - Round Cell Cancer (vs. RCC): HR 0.441
   - Non-Renal Carcinomas (vs. RCC): HR 0.481
   - Humeral Lesions (vs. Femoral): HR 0.399
   - Bisphosphonates (vs Denosumab): HR 0.422
2. **Surgical Failure (Fisher)**
   - Tumor Origin p=0.005
   - Extremity p=0.059
   - Gender p=0.087
   - Procedure p=0.066
   - Mirels Score p=0.048
3. **Survival**
   - **Antiresorptive Use (BP) HR 0.504, p=0.020**
   - Tumor Origin p=0.05
     - Lung (vs. RCC) HR 3.32, p=0.025
     - Prostate (vs RCC) HR 3.22, p=0.066

Failure & Radiographic Progression Rates		
	Failure	**Progression**
Overall	**16.85%**	**43.82%**
Renal Cell Carcinoma	30.77%	61.54%
Other Carcinomas: Breast, Prostate, Thyroid , Lung	12.0%	36.0%
Round Cell Cancers: Multiple Myeloma & Lymphoma	3.03%	30.3%
Male	25.71%	68.57%
Female	11.11%	27.78%
Femur	19.35%	48.39%
Humerus	0%	21.50%
All Fixation	22.22%	48.1%
IM Nail	24.32%	48.6%
Endoprosthesis	8.57%	37.1%
Densoumab Use	11.54%	60.0%
Bisphosphonate Use	20.0%	30.7%

Conclusion

1. Endoprosthetic Replacement > Fixation for Some Groups

- **Tumor Type**: Renal Cell Carcinoma > Non-Renal Carcinomas > Round-Cell
- **Location:** Femoral > Humeral lesions
- **Gender:** Men > Women

2. Antiresorptive Therapy should be utilized

- strong association with **patient survival**
- increased time to **radiographic progression** (bisphosphonates > denosumab)

Questions?

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Mirels, H. (1989). "Metastatic disease in long bones. A proposed scoring system for diagnosing impending pathologic fractures." Clin Orthop Relat Res(249): 256-264.
Harada, H., et al. (2010). "Radiological response and clinical outcome in patients with femoral bone metastases after radiotherapy." J Radiat Res **51**(2): 131-136.
Wedin, R., et al. (1999). "Failures after operation for skeletal metastatic lesions of long bones." Clin Orthop Relat Res(358): 128-139.
Ratasvuori, M., et al. (2013). "Insight opinion to surgically treated metastatic bone disease: Scandinavian Sarcoma Group Skeletal Metastasis Registry report of 1195 operated skeletal metastasis." Surg Oncol **22**(2): 132-138.
Wedin, R., et al. (2012). "Complications and survival after surgical treatment of 214 metastatic lesions of the humerus." J Shoulder Elbow Surg **21**(8): 1049-1055.
Lattinen, M., et al. (2015). "Survival and complications of skeletal reconstructions after surgical treatment of bony metastatic renal cell carcinoma." Eur J Surg Oncol.