Developmental Dysplasia of the Hip: Lessons Learned from a Multicenter Prospective Study

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An agency of the Provincial Health Services Authority

Disclosure

- **UBC Department of Orthopaedics:** Kishore Mulpuri
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  - **Editorial or governing board:** Journal of Pediatric Orthopedics

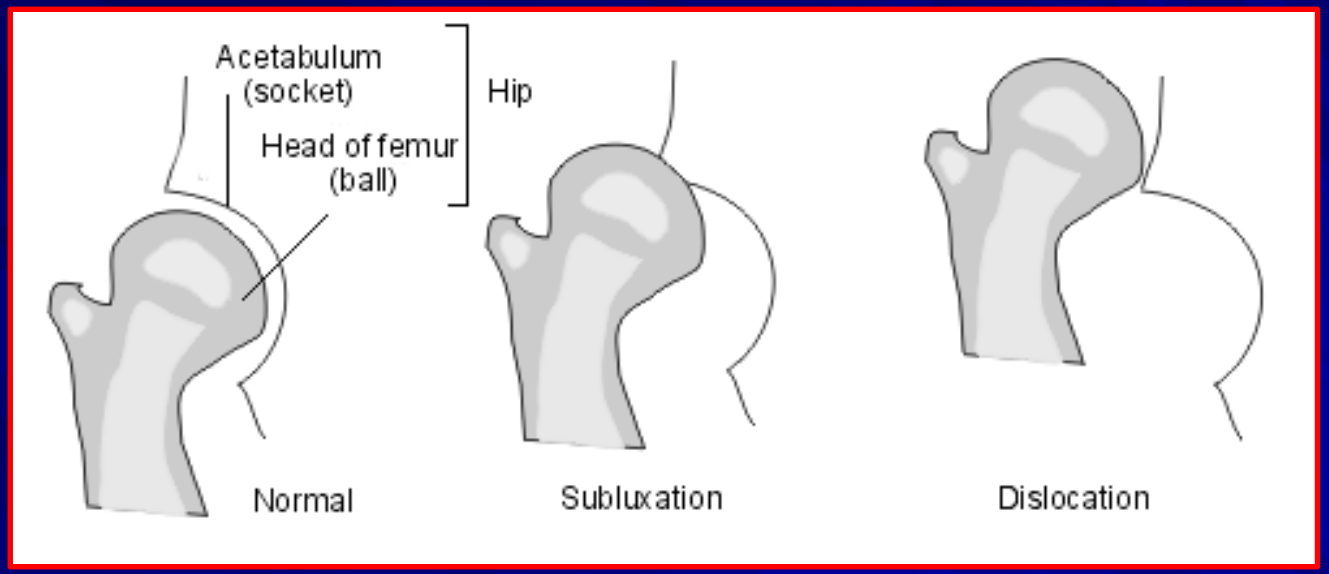
Mitigating Potential Bias

- Not Applicable

OBJECTIVES

- To describe the need for prospective study groups
- Classification and terminology of DDH
- Results and lessons learned from the IHD study

Developmental Dysplasia of the Hip (DDH)



- 2-3/1000 live births = dislocations
- 30-50/1000 live births = subluxations

DDH in the Literature

- **No fundamental improvements** in DDH management
- **Variable treatment** regimens and outcomes
- **Reiteration** of known successful treatments
- **Confusion** on classification terminology

AAOS

American Academy of Orthopaedic Surgeons

DETECTION AND NONOPERATIVE MANAGEMENT OF PEDIATRIC DEVELOPMENTAL DYSPLASIA OF THE HIP IN INFANTS UP TO SIX MONTHS OF AGE

EVIDENCE-BASED CLINICAL PRACTICE GUIDELINE

Adopted by the American Academy of Orthopaedic Surgeons Board of Directors
September 5, 2014

This guideline has been endorsed by the following organizations:

American Academy of Pediatrics
DEDICATED TO THE HEALTH OF ALL CHILDREN™

POSNA
The Pediatric Orthopaedic Society of North America

THE SOCIETY FOR PEDIATRIC RADIOLOGY

SOCIETY OF DIAGNOSTIC MEDICAL SONOGRAPHY
SDMS

Guideline Recommendations

- **2 *moderate*** evidence recommendations
- **7 *limited*** evidence/expert opinion recommendations
- ***No strong*** recommendations based on available evidence

Where Do We Go From Here?

- **Research!**
  - Multicentre studies
  - Prospective data collection
- Understand treatment outcomes
- Decrease variation in diagnosis, treatment
- **Improve patient outcomes**
  - Clinical and Quality of Life

Objective

To address the *gaps in evidence* for DDH management through a multicentre, international prospective study

Nine Affiliated Centres: Australia, Boston, Mexico, Orlando, Philadelphia, San Diego, Toronto, UK Vancouver

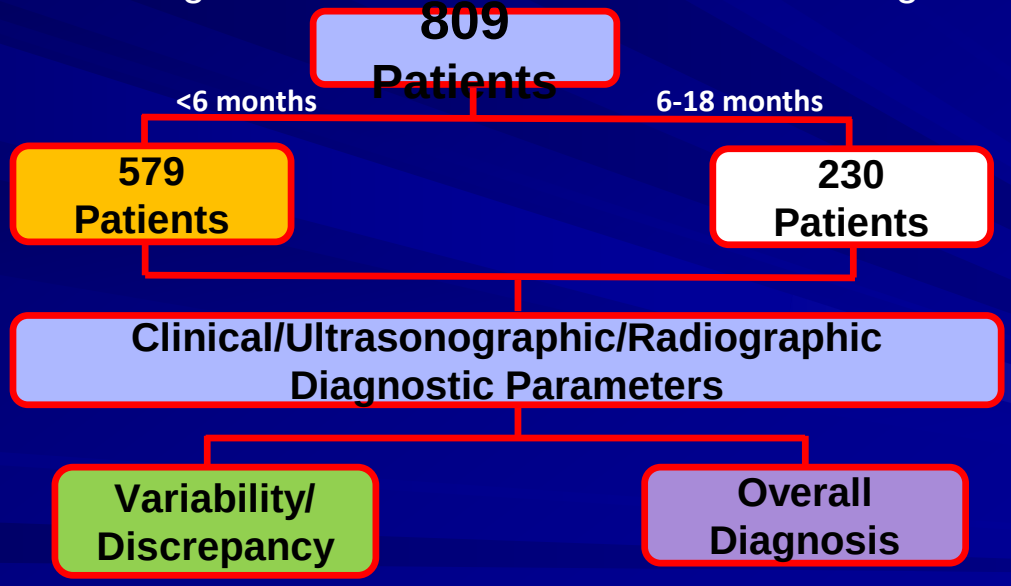
BCCH Coordinating Site

Kishore Mulpuri – Research Director

Methods

International Hip Dysplasia Institute (IHDI) Study Group:

Multi-center, prospective, international observational cohort study
Infants with dislocated hips at rest
Diagnosed between 0 and 18 months of age



Patient Demographics and Diagnostic Methods

Patient Demographics	
Sex (Male/Female)	686/123
Diagnosis Age (Median [Range])	1.5 months [0-18]
Fetal Presentation (Breech/Cephalic/Unknown)	207/568/34
Family History (Yes/No/Unknown)	251/533/61

Diagnostic Method	
Clinical/Ultrasound	504 (62.3%)
Clinical/Radiograph	223 (27.6%)
Clinical/Ultrasound/ Radiograph	17 (2.1%)
Ultrasound	46 (5.7%)
Radiograph	19 (2.3%)
Dynamic Assessment	716 (88.5%)

Study inclusion requirement: Imaging confirmation prior to treatment initiation

Diagnostic Outcomes and Discrepancies

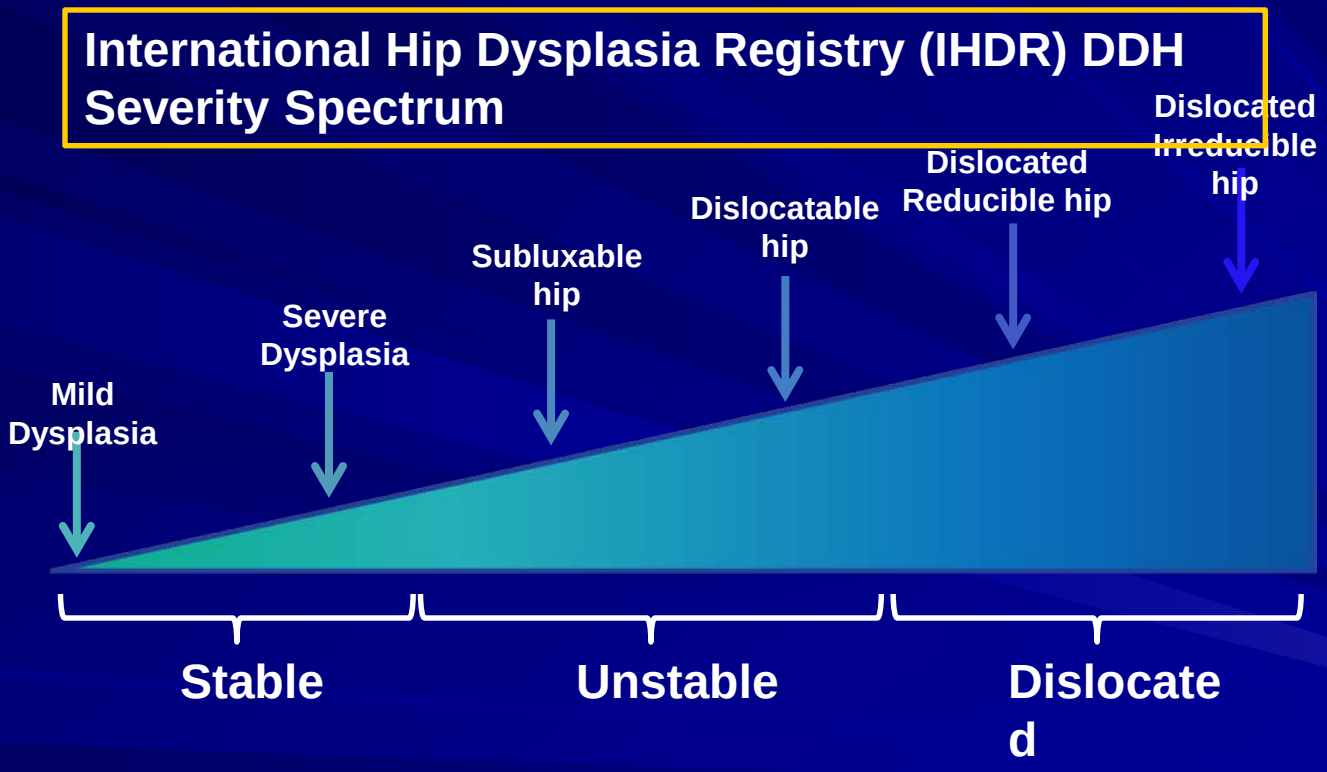
Diagnosis?	No Dislocation			
Dislocation		Clinical	Ultrasound	Radiograph
	Clinical		52	5
	Ultrasound	57		0
	Radiograph	6	0	

Diagnostic Discrepancy	
Clinical to Ultrasound	109/504 (21.6%)
Clinical to Radiograph	11/223 (4.9%)

- Discrepancy in clinical vs. radiologic diagnosis
  - Subjective definitions between surgeons, across centres

What is the gold standard diagnosis?

Complexity of DDH Diagnoses



Schaeffer EK et al. *Med J Aus.* 2018;208(8):359-364.

A Standardized Diagnostic Classification

Clinical		Radiographic		Overall Diagnosis (Clinical+XR)
Femoral Head	Joint Laxity	IHDI Grade	Acetabular Morphology	
Reduced	Stable	I	Normal	Normal
			Dysplastic	Dysplastic
		II	Normal	Subluxated
			Dysplastic	
	Unstable	I	Normal	Dislocatable
			Dysplastic	
		II	Normal	Dislocatable/Subluxated
			Dysplastic	
Dislocated	Reducible	III or IV	Normal	Dislocated Reducible
			Dysplastic	
	Irreducible	III or IV	Normal	Dislocated Irreducible
			Dysplastic	

Clinical		Ultrasound		Overall Diagnosis (Clinical+US)
Femoral Head	Joint Laxity	%FHC	Acetabular Morphology	
Reduced	Stable	>50	Normal	Normal
			Dysplastic	Dysplastic
		35-50	Normal	Subluxated
			Dysplastic	
	Unstable	>50	Normal	Dislocatable
			Dysplastic	
		35-50	Normal	Dislocatable/Subluxated
			Dysplastic	
Dislocated	Reducible	0-35	Normal	Dislocated Reducible
			Dysplastic	
	Irreducible	0-35	Normal	Dislocated Irreducible
			Dysplastic	

Conclusion and Significance

- Lack of a ***standardized diagnostic method*** and classification system has led to ***low-level evidence*** and ***lack of consensus*** across DDH literature
- Significant ***discrepancy*** exists among ***diagnostic methods***
- ***Subjective interpretation*** of diagnostic definitions limits cross-study and cross-centre comparison
- Development, dissemination of ***standardized classification*** system imperative to ***promote fundamental advancements*** in DDH diagnosis and management

Centre Variability and Diagnostic Classification

What Is the Impact of Center Variability in a Multicenter International Prospective Observational Study on Developmental Dysplasia of the Hip?

Kishore Mulpuri MBBS, MS(Ortho) MHSc(Epi), Emily K. Schaeffer PhD, Simon P. Kelley MBChB, FRCS (Tr and Ortho), Pablo Castañeda MD, Nicholas M. P. Clarke ChM, DM, FRCS, FRCS Ed, Jose A. Herrera-Soto MD, Vidyadhar Upasani MD, Unni G. Narayanan MBBS, MSc, FRCSC, Charles T. Price MD, FAAP, IHDI Study Group

Clin Orthop Relat Res
DOI 10.1007/s11999-016-4746-y

Classification	Hip Status	
	Right	Left
Bilateral Dislocated	Dislocated	Dislocated
Unilateral Dislocated	Normal	Dislocated
	Dislocated	Normal
Bilateral Dysplastic	Dysplastic	Dysplastic
Unilateral Dysplastic	Normal	Dysplastic
	Dysplastic	Normal
Bilateral Hybrid	Dislocated	Dysplastic
	Dysplastic	Dislocated

Risk Factors for Late-Presenting DDH

What Risk Factors and Characteristics Are Associated With Late-presenting Dislocations of the Hip in Infants?

Kishore Mulpuri MBBS, MS(Ortho), MHSc(Epi), Emily K. Schaeffer PhD, Janice Andrade BSW, Wudbhav N. Sankar MD, Nicole Williams BMedSc, FRACS(Ortho), Travis H. Matheney MD, MLA, Scott J. Mubarak MD, Peter J. Cundy MBBS, FRACS, Charles T. Price MD, FAAP, IHDI Study Group

Clin Orthop Relat Res
DOI 10.1007/s11999-015-4668-0

- **Late-presenting DDH (>3 months at diagnosis)**
  - **more complex treatment, long-term complications**

- **Factors associated with late presentation:**
  - **Cephalic presentation at birth**
  - **History of swaddling**
  - **Unilateral dislocation**
  - **Irreducible dislocation**

Outcomes of Brace Treatment in DDH

Evaluation of Brace Treatment for Infant Hip Dislocation in a Prospective Cohort

Defining the Success Rate and Variables Associated with Failure

Vidyadhar V. Upasani, MD, James D. Bomar, MPH, Travis H. Matheney, MD, Wudbhav N. Sankar, MD, Kishore Mulpuri, MBBS, MS(Ortho), MHSc(Epi), Charles T. Price, MD, Colin F. Moseley, MD, CM, FRCS, Simon P. Kelley, MBChB, MRCS, FRCS, Unni Narayanan, MBBS, MSc, FRCS(C), Nicholas M.P. Clarke, ChM, DM, FRCS, John H. Wedge, OC, MD, FRCSC, Pablo Castañeda, MD, James R. Kasser, MD, Bruce K. Foster, MBBS, MD, FRACS, Jose A. Herrera-Soto, MD, Peter J. Cundy, MBBS, FRACS, Nicole Williams, FRACS, BMed, BMedSc, and Scott J. Mubarak, MD

Level of Evidence: Prognostic Level I.

- **Primary brace treatment successful in 79% of infants**
  - **dislocated hip diagnosed <6 months of age**
- **Factors associated with brace failure:**
  - **Severity of dislocation**
  - **Age at treatment**
  - **Brace type**
  - **Hip affected**

Management of Irreducible Hip Dislocations in Infants With Developmental Dysplasia of the Hip Diagnosed Below 6 Months of Age

Alex Aarvold, BS, ChB, FRCS (Ortho), MB, MD, Emily K. Schaeffer, PhD,†‡ Simon Kelley, MBChB, FRCS (Tr and Orth),§ Nicholas M.P. Clarke, ChM, FRCS, FRCSEd,* Jose A. Herrera-Soto, MD,‖ Charles T. Price, MD, FAAP,‖ IHDI Study Group,‖ and Kishore Mulpuri, MBBS, MS (Ortho), MHSc (Epi)†‡*

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Conclusions

- Pavlik harness treatment has been demonstrated to be a safe first-line treatment for infants with dislocated irreducible hips

- Left hips were more likely to be successfully reduced in pavlik harness

Outcomes of Surgical Treatment in DDH

Closed Reduction for Developmental Dysplasia of the Hip: Early-term Results From a Prospective, Multicenter Cohort

Wudbhav N. Sankar, MD, Alex L. Gornitzky, BS,* Nicholas M.P. Clarke, MD,† José A. Herrera-Soto, MD,‡ Simon P. Kelley, MD,§ Travis Matheney, MD,‖ Kishore Mulpuri, MBBS, MS (Ortho), MHSc,¶# Emily K. Schaeffer, PhD,¶# Vidyadhar V. Upasani, MD,** Nicole Williams, MD,††‡‡ Charles T. Price, MD,‡ and International Hip Dysplasia Institute*

Level of Evidence: Level II—prospective observational cohort.

In the literature: early CR increases risk of avascular necrosis (AVN) than delayed OR due to absence of ossific nucleus

Variable	CR	OR
Patients	78	62
Hips	87	69
Initial Success	79/87 (91%)	68/69 (99%)
Initial Failure	8/87 (9%)	1/69 (1%)
Redislocation	7/79 (9%)	0/68 (0%)
Further Corrective Surgery	8/72 (11%)	3/68 (4%)
AVN	18/72 (25%)	18/69 (26%)
ON present	8/39 (21%)	12/43 (28%)
ON absent	10/33 (30%)	6/20 (23%)

Developmental dysplasia of the hip: addressing evidence gaps with a multicentre prospective international study

Emily K Schaeffer[1,2], IHDI Study Group[3], Kishore Mulpuri[1]

Med J Aust. 2018 May 7;208(8):359-364.

The Need for Further Corrective Surgery in Developmental Dysplasia of the Hip:

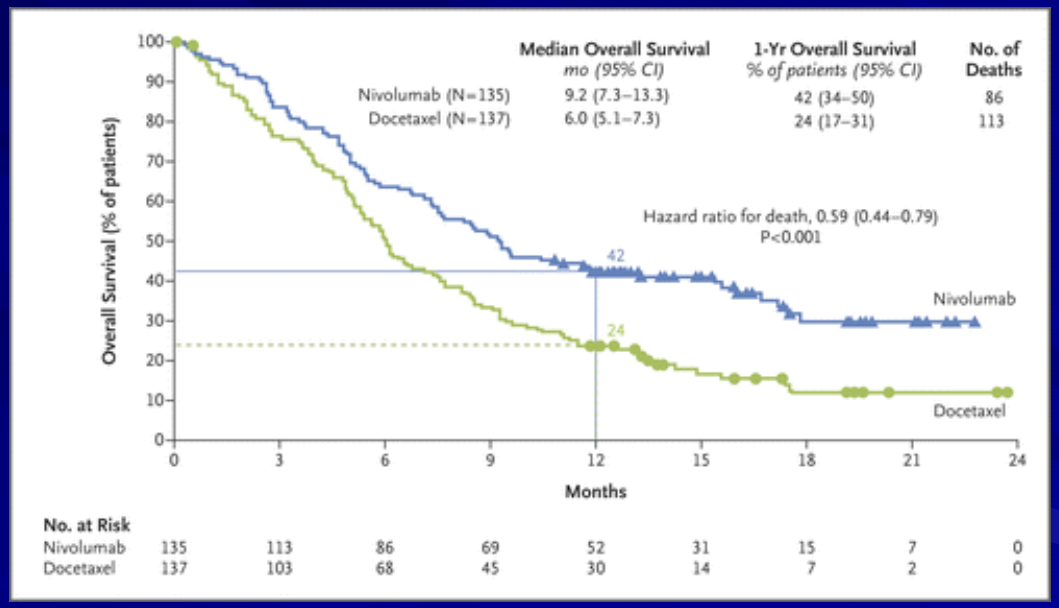
Surgical Decision-making and Practice Variability

Emily K Schaeffer PhD; Nicholas MP Clarke, CHM, DM, FRCS; Alaric Aroojis, MBBS, MS(Ortho); Charles Price MD, FAAP; Kishore Mulpuri MBBS, MS(Ortho), MHSc(Epi); and

The IHDI Study Group

Outcome Measures in the Medical Literature

- **Cancer therapy/drug trials:**
  - **patient death = true *objective* outcome for survival analysis**



Outcome measures in Orthopaedic Surgery?

Brahmer et al., NEJM 2015;373:123-135.

Outcome Measures in Orthopaedic Surgery

- ***Subjective*** **outcome measures common in orthopaedic surgery**
  - **Secondary/revision surgery**
  - **Grading of Complications**
  - **Grading/ treatment of Infection**

- **Outcomes can depend upon:**
  - **Hospital/medical system**
  - **Patient geographic location**
  - **Patient preference**
  - ***Surgeon decision-making***

Survival Analysis in Orthopaedic Surgery

- **Secondary/revision surgery = common outcome for survival analysis**

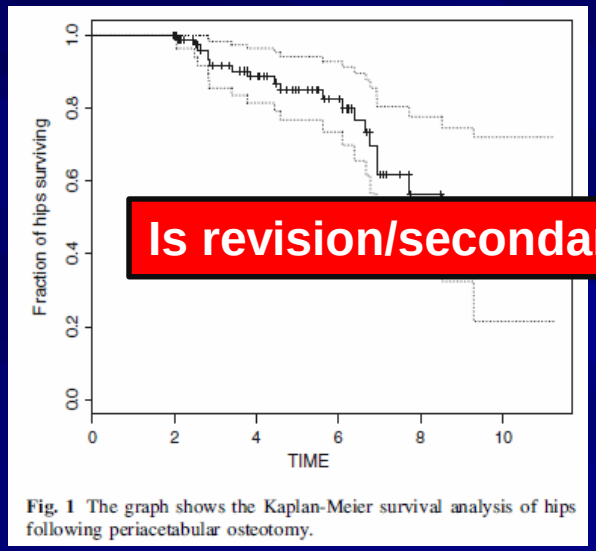
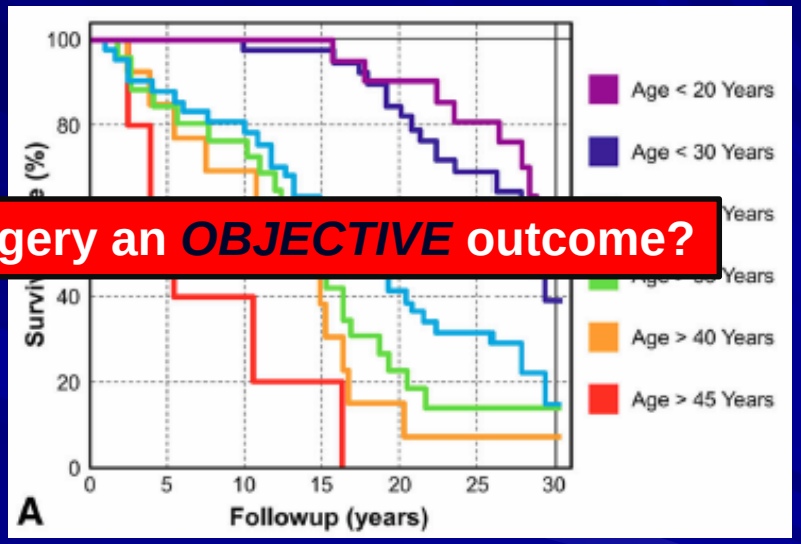


Fig. 1 The graph shows the Kaplan-Meier survival analysis of hips following periacetabular osteotomy.



Is revision/secondary surgery an *OBJECTIVE* outcome?

Periacetabular Osteotomy (PAO) survival endpoint = conversion to THA

Millis et al., CORR 2009;467:2228-2234.
Lerch et al., CORR 2017;475:1154-1168.

Example Case: PAO Survival

A patient undergoes a periacetabular osteotomy (PAO) at 15 years of age:

USA:

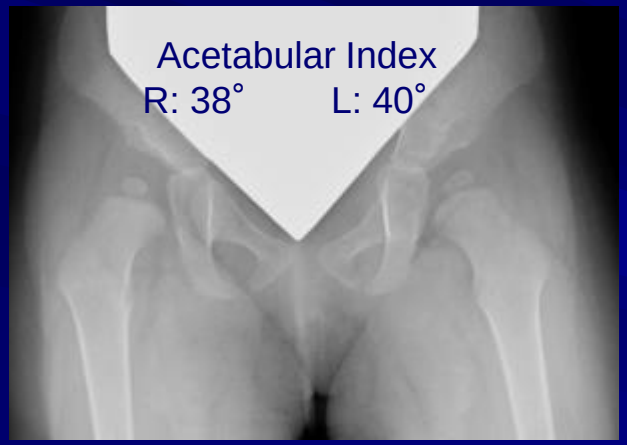
Canada:

India:

Case Example – Patient 8

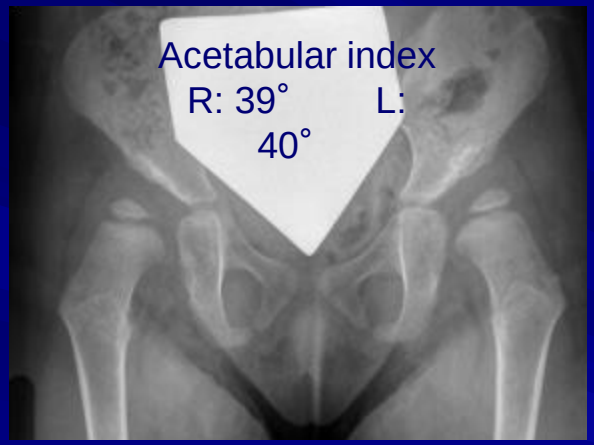
Diagnosed with bilateral dislocated hips at 16 months of age

Underwent closed reduction, spica casting at 18 months



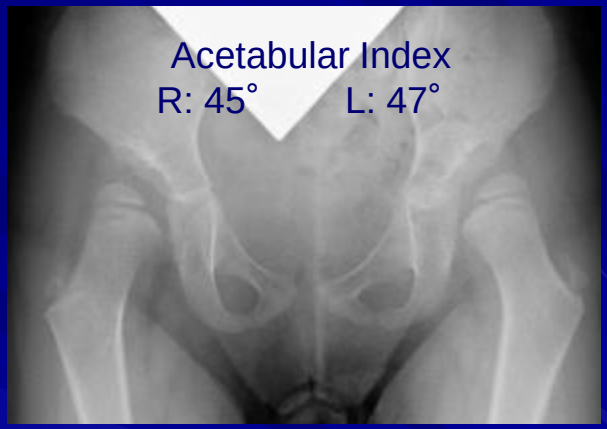
Age: 2 years 2 months

8 months post-CR



Age: 2 years 10 months

12 months post-CR



Age: 3 years 6 months

2 years post-CR

INTERNATIONAL HIP DYSPLASIA INSTITUTE

FCS as a Surrogate Outcome Measure

Many studies use FCS as an indication of success or failure of initial procedure

Predictors for Secondary Procedures in Walking DDH

Purushottam A. Gholve, MD, MBMS, MRCS, John M. Flynn, MD,† Matthew R. Garner, MD,‡ Michael B. Millis, MD,* and Young-Jo Kim, MD, PhD**

Background: Persistent or recurrent hip dysplasia and/or loss of reduction can complicate the treatment of developmental dysplasia of the hip (DDH) in walking children. In this study, we identify predictors for secondary procedures after open reduction of the hip in walking children with DDH.

Level of Evidence: Retrospective case series, level IV.

Key Words: DDH, hip dysplasia, open reduction of hip, pediatric hip

(*J Pediatr Orthop* 2012;32:282–289)

FCS decisions and timing can be **dependent upon surgeon preference**

Evaluation of Experienced Surgeons' Decisions Regarding the Need for Secondary Surgery in Developmental Dysplasia of the Hip

Hakan Ömeroğlu, MD, Haluk Ağuş, MD,† Ali Biçimoğlu, MD,‡ and Yücel Tümer, MD§*

Case Example: Minimal Agreement

Age: 19 months

13 months post-OR

Standardized consensus = 0

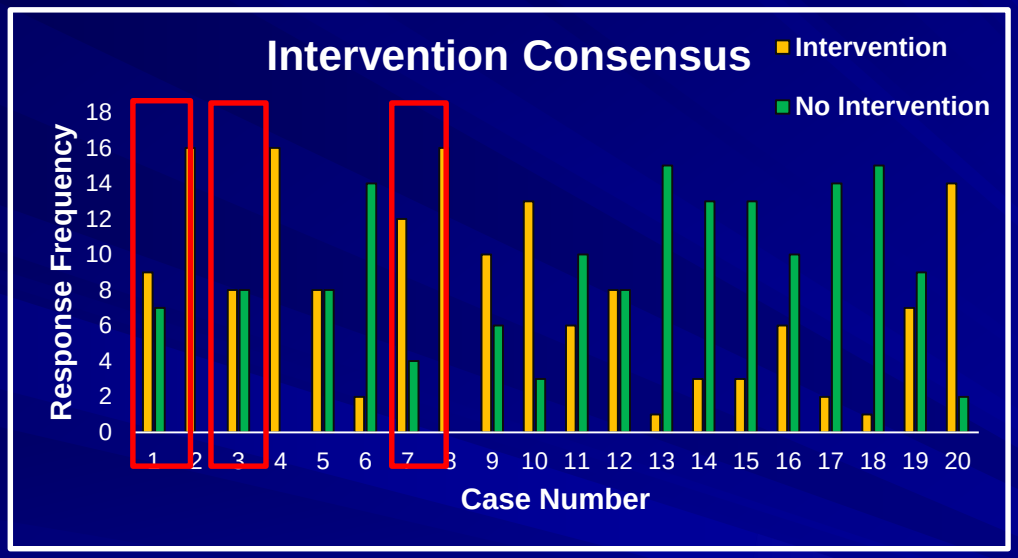
8/16 surgeons WOULD perform an intervention

- Arthrogram to assess need for further procedures (1)
- Femoral Varus Osteotomy (1)
- Pelvic Osteotomy (Dega) (2)
- FVO + PO (Salter) (1)
- Open Reduction (OR) + PO (1)
- OR + FVO (1)
- Abduction Bracing (1)

8/16 surgeons WOULD NOT perform an intervention

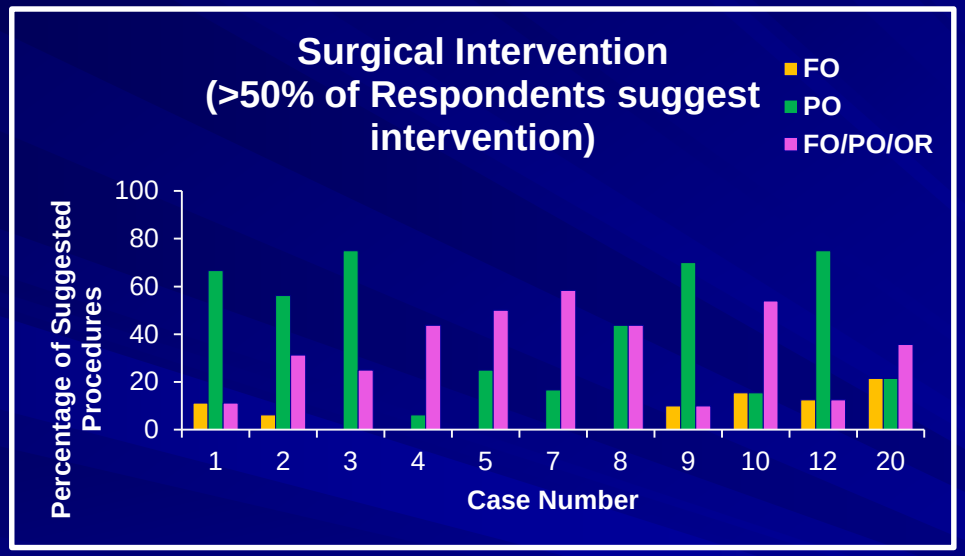
- POSSIBLE need for future intervention (5)
  - 4 – PO
  - 1 – PO + OR
- DEFINITE need for future intervention (3)
  - 1 – PO
  - 1 – FVO + PO + OR
  - 1 – FVO + PO

Intervention Consensus



- **Unanimous agreement : 3/20 cases (15%)**
- **Average standardized consensus (0-1 scale): 0.52 [0.34,0.70]**

Surgical Procedure Choice



- Considerable variation in procedure choice

- Pelvic osteotomy (PO) (41%), combined pelvic and femoral osteotomy (PO/FO) (24%) = most frequent procedure choices

Conclusions

IHDI has demonstrated the power of prospective study groups to generate high quality evidence with practice-changing potential:

- **Developed diagnostic algorithms**
- **Identified risk factors**
- **Challenged previous retrospective findings**

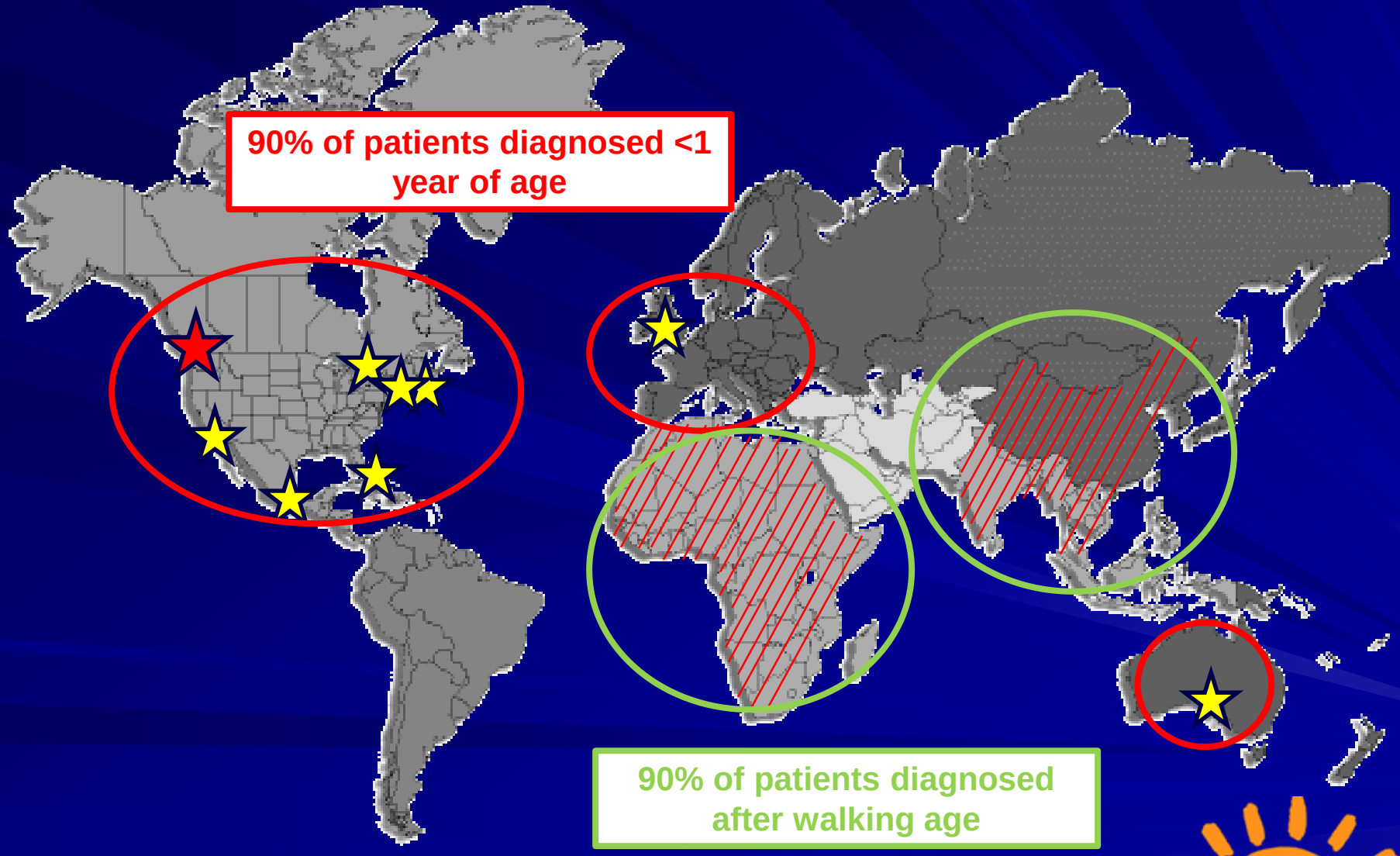
***BUT,* early-term results *ALSO* demonstrate need for comprehensive, long-term follow-up**

Unanswered Questions

Even in the developed world:

- Many ***unanswered questions*** regarding screening, diagnosis, treatment, management
- Large ***practice variability*** surgeon-to-surgeon, centre-to-centre
- Limited ability to identify ***optimal management*** strategies

DDH and Under-served Areas



Development of an International Hip Dysplasia Registry (IHDR)

Hypothesis-Generating:

DDH Registry (Housed at BCCH)

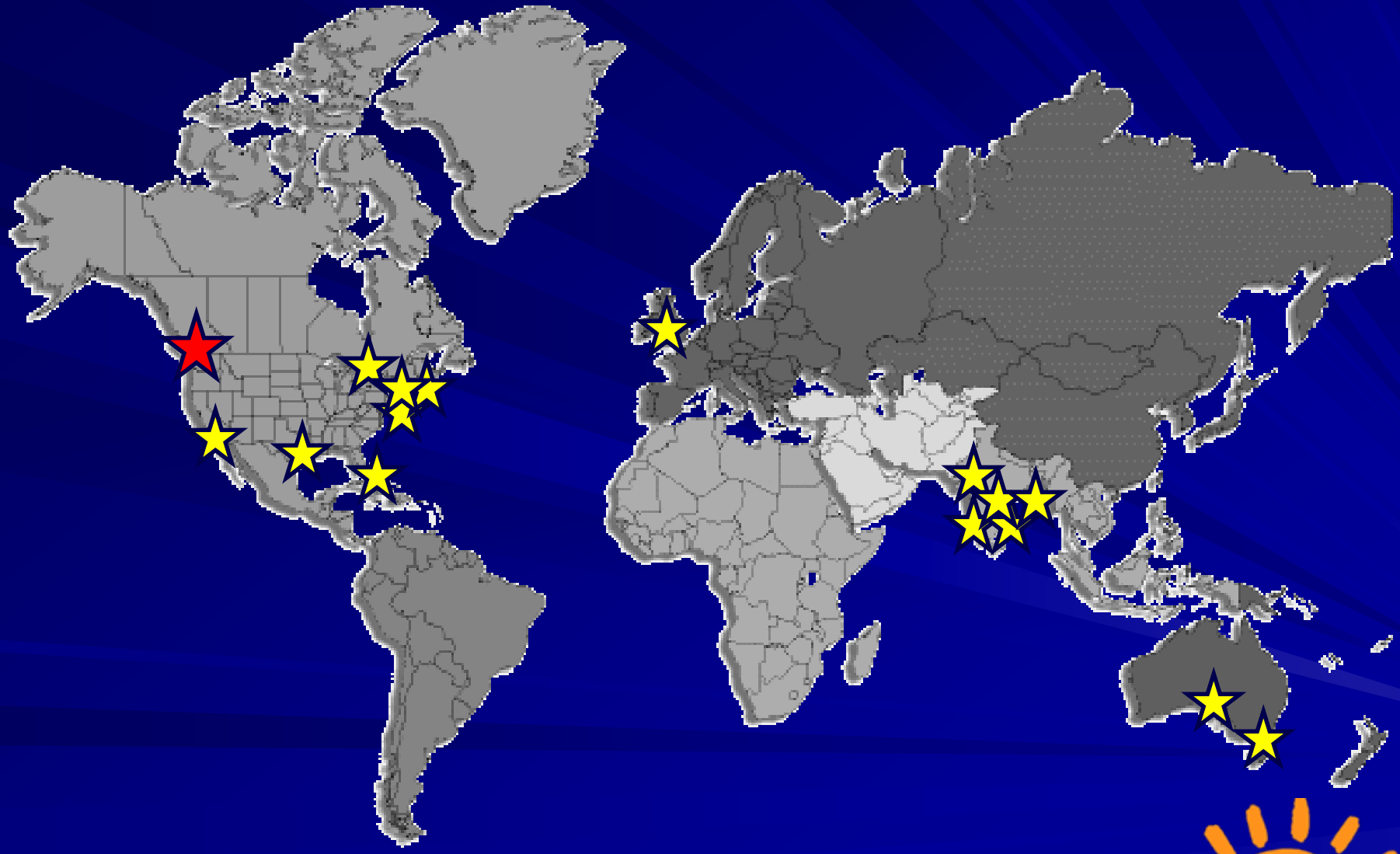
FULL SPECTRUM of DDH
Follow-up to skeletal maturity

Hypothesis-Testing:

e.g.

- **RCT – Rigid vs. Dynamic Bracing**
- **RCT – DDH risk factor screening and monitoring**
- **RCT – Observation vs. Pavlik for dysplastic, clinically stable hips**

Potential for Global Impact



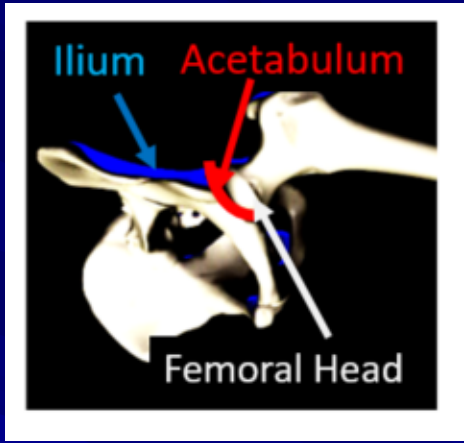
3D Ultrasound in the Management of Developmental Dysplasia of the Hip

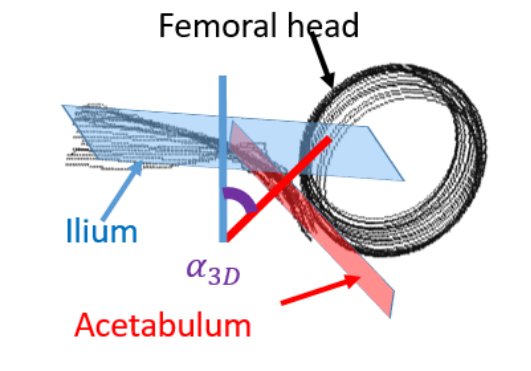
Niamul Quader MS; Emily Schaeffer PhD

Kishore Mulpuri MBBS; Anthony Cooper FRCS (Ortho)

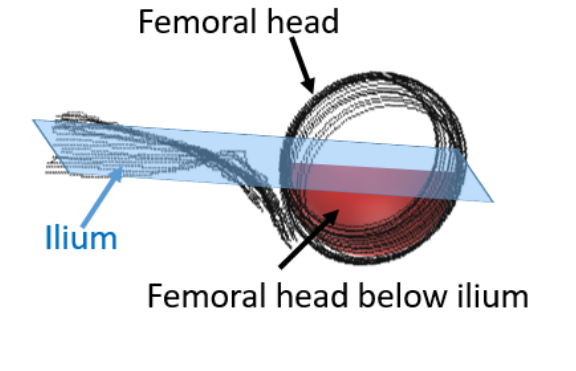
Antony Hodgson PhD; Rafeef Abugharbieh PhD

Proposed 3D-derived Dysplasia Metrics





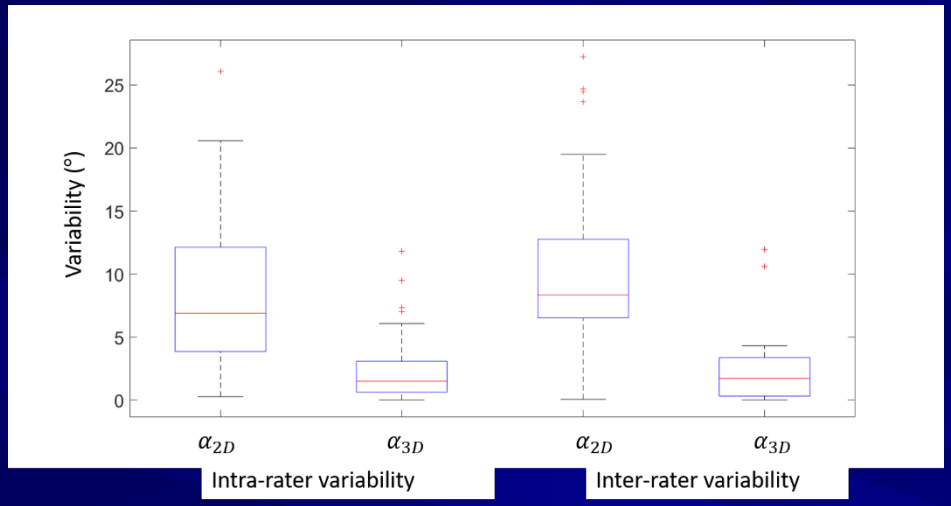
α_{3D}



FHC_{3D}

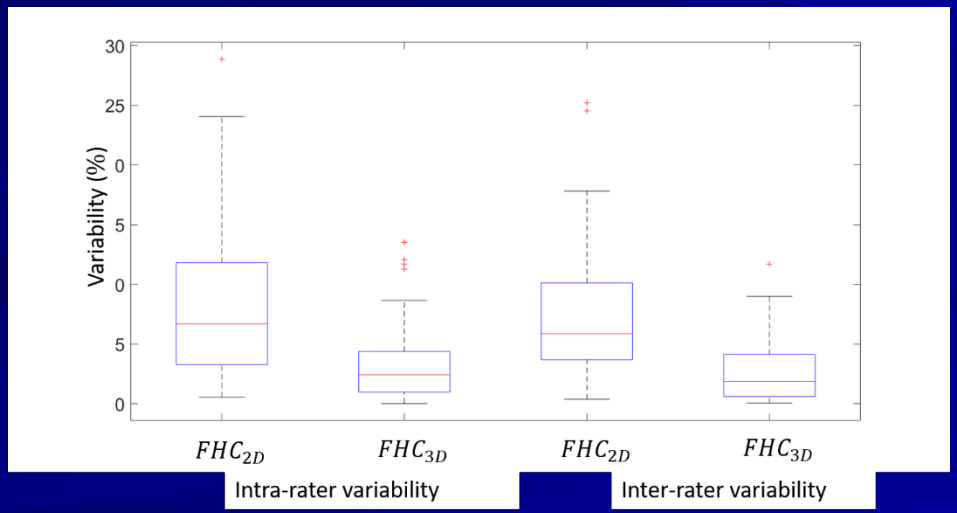
Variability, 2D/3D

α_{3D} vs. α_{2D}



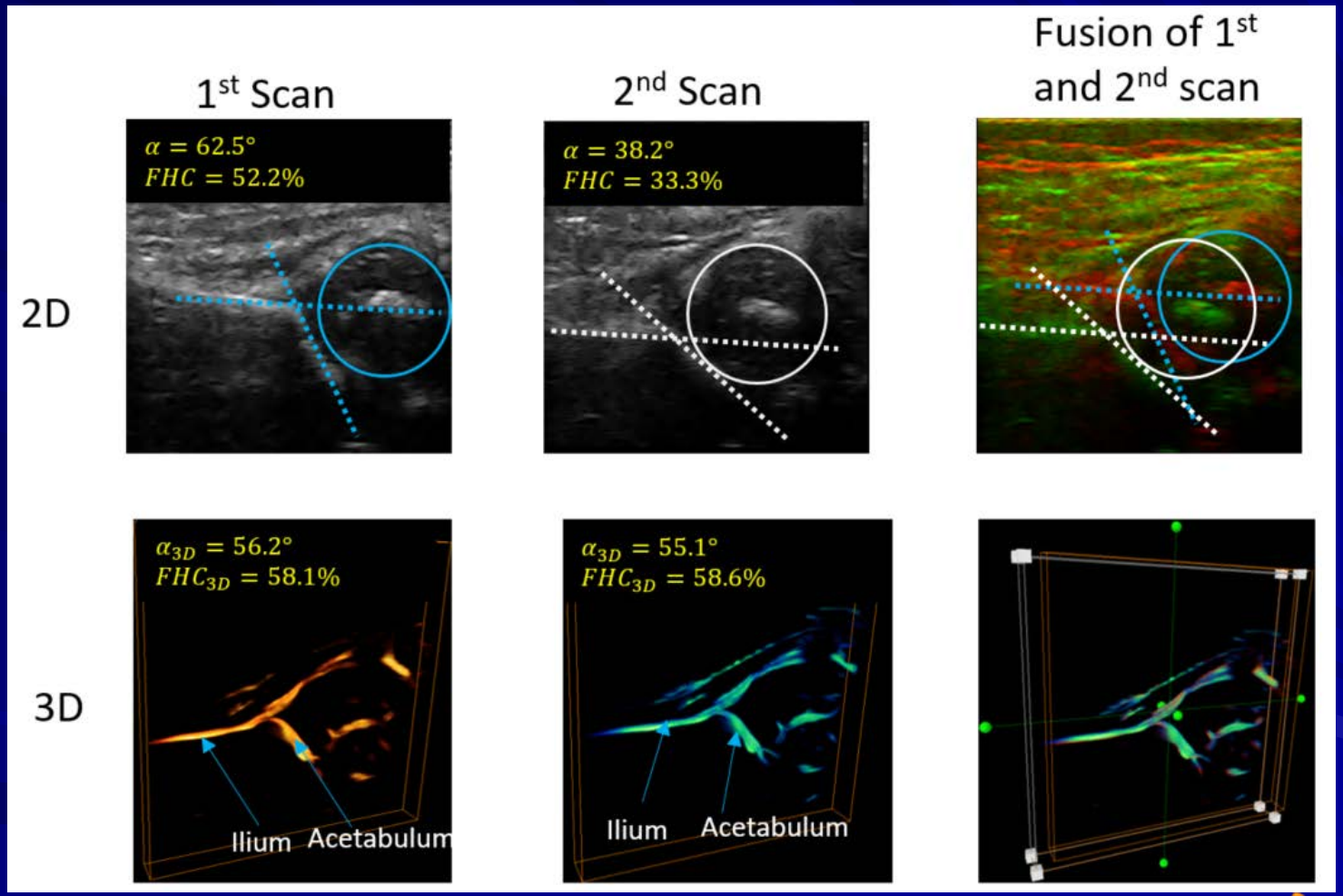
- **Statistically significant reduction in variability for α_{3D} compared to α_{2D}**

FHC_{3D} vs. FHC_{2D}



- **Statistically significant reduction in variability forFHC_{3D} compared to FHC_{2D}**

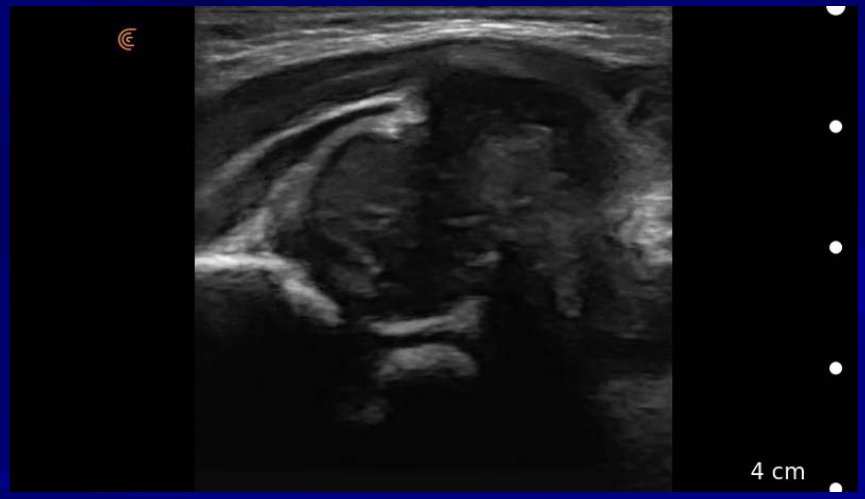
Example Result, and Intuition for Reduced Variability with 3D



Future Directions

Clarius: Wireless Portable Ultrasound

Linear Handheld Ultrasound Scanner



Future Directions

Clarius: Wireless Portable Ultrasound

Linear Handheld Ultrasound Scanner

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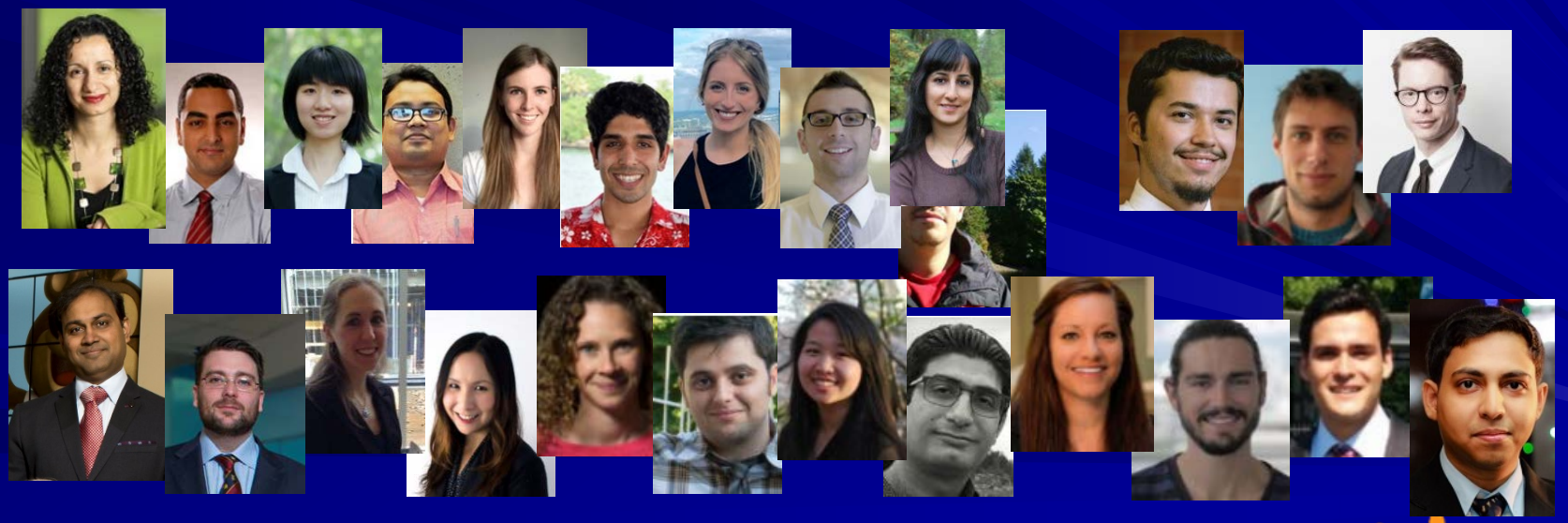

Acknowledgements

IHDI Study Group Members

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- John H. Wedge
- Nicole Williams

IHDR Investigators

- Charles T. Price
- Alexander Aarvold
- Tony Cooper
- Emily Dodwell
- Leo Donnan
- Jose A. Herrera-Soto
- Simon P. Kelley
- Harry Kim
- Travis H. Matheney
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