Slide 1

Artificial intelligence augmented ultrasound detection of hip dysplasia

Jacob Jaremko, MD, PhD
MALMIC April 2023

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Slide 2

My current roles

- Professor, Radiology
- Adjunct Professor, Computing Science

- Canada CIFAR AI Chair

- Partner, Medical Imaging Consultants

- Co-founder, MEDO.ai

- Fellow, AMII

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Slide 3

Developmental Dysplasia of Hip (DDH)

- Common (1/100)
- Abnormal bony shape → unstable joint → premature arthritis
- Preventable if detected in infancy

Dysplastic   Normal

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**Slide 4**

Original idea Down Under

- During clinical fellowship training
- Learning to perform hip dysplasia ultrasound
- Sonographer Cain Brockley: why can't we look at whole 3D shape of hip?

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Slide 5

DDH Screening

- Every day in Alberta…
    - ~4 children (1 Indigenous) born with DDH
    - ~2 hip arthroplasties for OA from DDH

- 95% of infant DDH is cured by wearing a soft harness for 6 weeks

- Graf ultrasound screening
    - Many false positives
    - Too costly for general use

- Can we screen with US/AI?

labrum
iliac wing
femoral head
os ilium
os ischium

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Slide 6

DDH – Alpha Angle

>60°
Normal

40°
Dysplastic

Normal   Dysplastic

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Ideal scenario for screening

- Relatively common disease
  - Especially in Indigenous
- Costly lifelong morbidity when missed
- Highly effective treatment available when detected.
- Harmless screening test (ultrasound)

- Why don't we screen worldwide?

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2D US not recommended for screening

- False positives
  - Recall for costly follow-up exams
- False negatives
  - Missed late presentation DDH
- Unreliable indices
- Limited prognostic information
 - Cochrane review 2011, AAP (Shaw 2016), "Choosing Wisely"

The Opportunity:
Screen for DDH with a better test!

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Hip 3D Ultrasound

Commercial linear probes
Mechanical sweep
Scan time:
 Philips 3.2 s, Xmatrix 0.6 s
  Canon <2 s

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'Sweep' video ultrasound

- User saves the entire video clip as they 'sweep' through the hip.
- Possible on any modern ultrasound probe
- Captures the whole hip shape
- Expert user or AI can analyze images afterward: normal or dysplastic?
- "3D" ultrasound = automated sweep
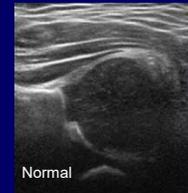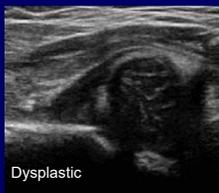
Dysplastic   Normal

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Dornoosh Zonoobi, MEng, PhD
Abhilash Hareendranathan, PhD
Emanuel Mostofi, BSc
Myles Mabee, MSc
Saba Pasha, PhD
Dana Cobzas, PhD
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Jacob L. Jaremko, MD, PhD, FRCPC

Developmental Hip Dysplasia Diagnosis at Three-dimensional US: A Multicenter Study[1]

Radiology: Volume 287: Number 3—June 2018 • radiology.rsna.org

- We tested 'sweep' method using 3D ultrasound probes
- Borderline = Graf IIa (return for follow up scan)
- In 1,728 hips, 3DUS reduced borderline cases by nearly 75%

Conventional
14%
8%
Normal
Borderline
Dysplastic
78%

Sweep method
15%
2%
Normal
Borderline
Dysplastic
83%
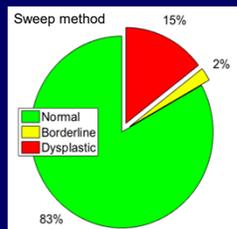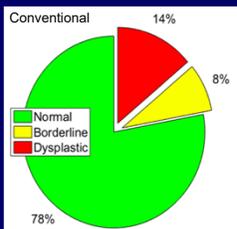
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3D ultrasound image analysis

- Manual segmentation
- Tedious - 250 slices
- "Labor of love"

- Can we automate this?
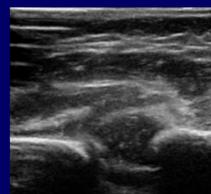
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Easy screening?

- If analysis could be automated → population screening
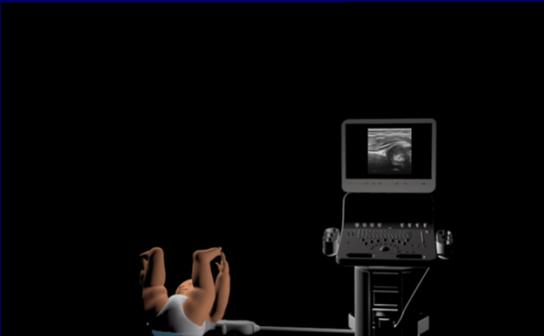
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Artificial Intelligence (AI) Image Analysis

- Smartphones now recognize faces
- Computers can now also recognize pathology in medical images.
- Convolutional neural network (CNN)
  - Input: entire image
 - Output: *numbers*, or *an image highlighting abnormalities*.
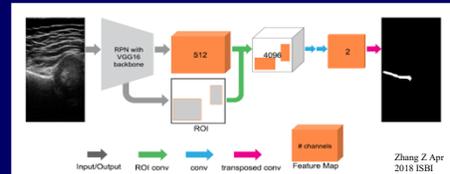
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AI software to assist radiologists

- Example: Osteodetect
- US FDA approved: finds fractures in Xray by AI
- Many similar products rapidly emerging
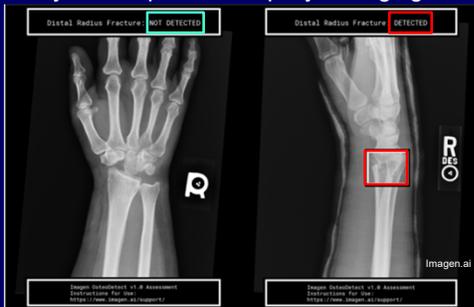
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EU Approves First AI For Analyzing X-Rays Automatically

By Adrianna Nine on April 7, 2022 at 5:30 am | Comments

- Oxipit ChestLink; has CE mark
- 3-step onboarding per site:
  - Initial retrospective phase
  - Prospective 'in parallel' phase
  - Autonomous phase
- All 'normal with high confidence' CXR can be removed from workflow (expected 15-40% of CXR)
- Heatmaps supplied for abnormal CXR

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ChestLink performance

- Tested in Finland
- 10,000 CXR, clinics; 45% normal
- AI picked 1,692 normal, of which 9 false negative
  - ?cardiomegaly, ?atelectasis, 1 small effusion
  - No serious miss; SN 99.8%, SP 36.4%
- AI could have removed 1/3 of normal CXR from queue
- Cost savings? Relevance to hospital work? Benefits?
  - *Keski-Filppula 2022, unpublished*

False negative: ?L effusion

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AI Strategies

- CNN → Shape analysis
  - identifies anatomy; output is shape mask
  - Then conventional methods for indices & diagnosis
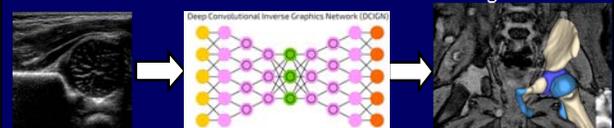
- End to end ANN
  - Initial layers are convolutional
  - Final fully connected layers predict Dx

Normal

Dysplastic
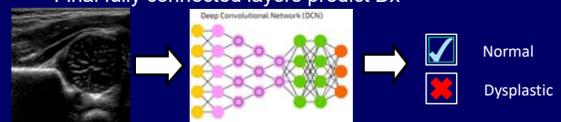
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Automated image segmentation

- Deep learning to replace user identification of seed points
- Series of 2D and 3D CNN, use info from adjacent slices
- Eventually successful
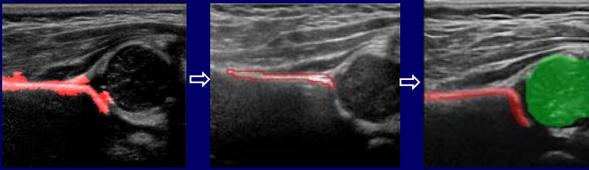
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Interest is spreading

- Vancouver

Ultrasound in Medicine & Biology
Volume 47, Issue 9, September 2021, Pages 2713-2722

Original Contribution

Automatically Delineating Key Anatomy in 3-D Ultrasound Volumes for Hip Dysplasia Screening

Houssam El-Hariri, Antony J. Hodgson, Kishore Mulpuri, Rafeef Garbi

- China

Diagnosis of Infantile Hip Dysplasia With B-Mode Ultrasound via Two-Stage Meta-Learning Based Deep Exclusivity Regularized Machine

Publisher: IEEE

Bangming Gong ; Jing Shi ; Xiangmin Han ; Huan Zhang ; Yuemin Huang ; Liwei Hu ; Jun Wang ; Jun Du ; Jun Shi   All Authors

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Automated image segmentation

- Getting easier on natural images
- 2023: Facebook Segment-Anything model
- Likely also works with ultrasound

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MEDO.ai

- Med-tech startup company
- Singapore / Edmonton 2018
- Acquired by Exo Inc. (USA) in mid 2022

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MEDO Web App (2019)

- Works on browser, eg. Chrome
- Automatically detects hip anatomy
- Calculates probability of hip dysplasia
- Generates report to assist radiologist
- US FDA approved; Health Canada ITA granted.

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Tablet/Smartphone App (2021)

- US probe plugs in via USB
- App runs entirely on an Android OS device
- No delays for upload/download
- Near-instant diagnosis
- Can use at any point of care

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Tablet/Smartphone App (2021)

- Video of tablet screen while scanning baby

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Mobile app report

This scan was done as part of a pilot study of Medo Hip AI. Patient data and consents were collected using the REDCap electronic data capture software.

REDCap Identifier:	1000034	Scan Date:	26 Apr. 2021
Location:	Westview PCN	Clinician:	

Findings	Left Hip	Left Hip
Alpha Angle	59°	61°
Coverage	41%	44%

Conclusion

Both hips are healthy: no follow up is required.

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DDH Screening Pilot Study for AICE

- 3 Sites
  - Spruce Grove
    - Westland
    - Westview
  - Red Deer
    - Saint Mary's

- Supported by grant (AI-CE)

ALBERTA INNOVATES
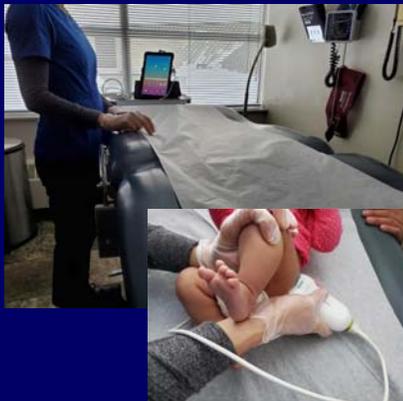
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Results

- 2 years (2021-23)
- 799 scans / 679 infants
- 90% scanned only by nurses
- 11 babies (1.5%) DDH
  - No risk factors or signs: 5
  - Indigenous: 1
  - 3 cast, 2 surgical
- Internal FU in 52 (8%)
  - 26 AI+, 26 technical failure
- External FU in 23 (3%)
  - SP **98%**, PPV **48%**
  - SN, NPV TBD…
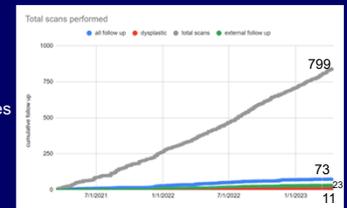
|	+ DDH	- DDH	
+ Scan	11	12	PPV = 48%
- Scan	0	674	-
		Specificity = 98%	

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Pilot study conclusions

- US/AI DDH screening at point of care is feasible
- Results ~ expert screening
  - Rosendahl 1994 in-hospital: 14% FU rate, ours 3-8%
  - DDH rate detected = 1.5%
- Already helping babies
  - 5 treated who would have been missed

- Next steps:
  - Integrate hardware into app
  - Add treatment at point-of-care
  - Implement zone-wide, Indigenous sites

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AI in ultrasound - opportunity

- Handheld ultrasound at point of care
- Don't bring patient into hospital, bring expertise to the patient
- AI to interpret images for users
- 21st century stethoscope
- Example of successful commercialization in progress

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