USE CASE Automatic identification of orthopaedic implants using AI

VINEET BATTA

Senior Clinical Fellow

Luton & Dunstable University Hospital NHS Trust

Automated Orthopaedic Implant Identification

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Dr. Vineet Batta

MBBS, MS(Orth), Dip SEM, FRCS (Orth), MD (BioMed Eng.) UCL

Orthopaedic & Trauma Surgeon

Luton & Dunstable University NHS Hospital, Luton, UK

Research Associate Royal National Orthopaedic Hospital, London ,UK

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Queen Mary University of London

Imperial College London

LUTON & DUNSTABLE UNIVERSITY HOSPITAL

Disclosures

- No Industry affiliations
- CEO of Unicorn Medics , UK Ltd
- Fellow Royal College of Surgeons , England
- Member British (BOA) & Indian (IOA) Orthopaedic Association
- Grant received from UKRI : Innovation

Teamwork : Grateful to all my Collaborators

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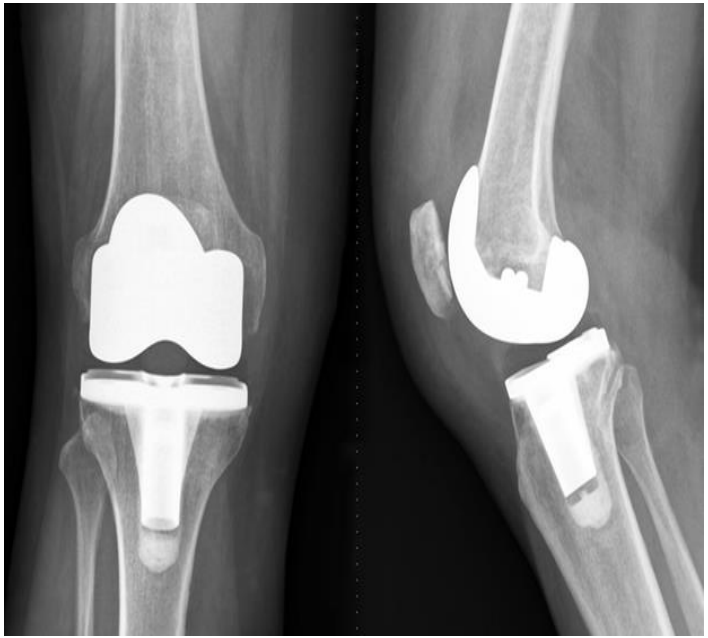
Luton & Dunstable University Hospital

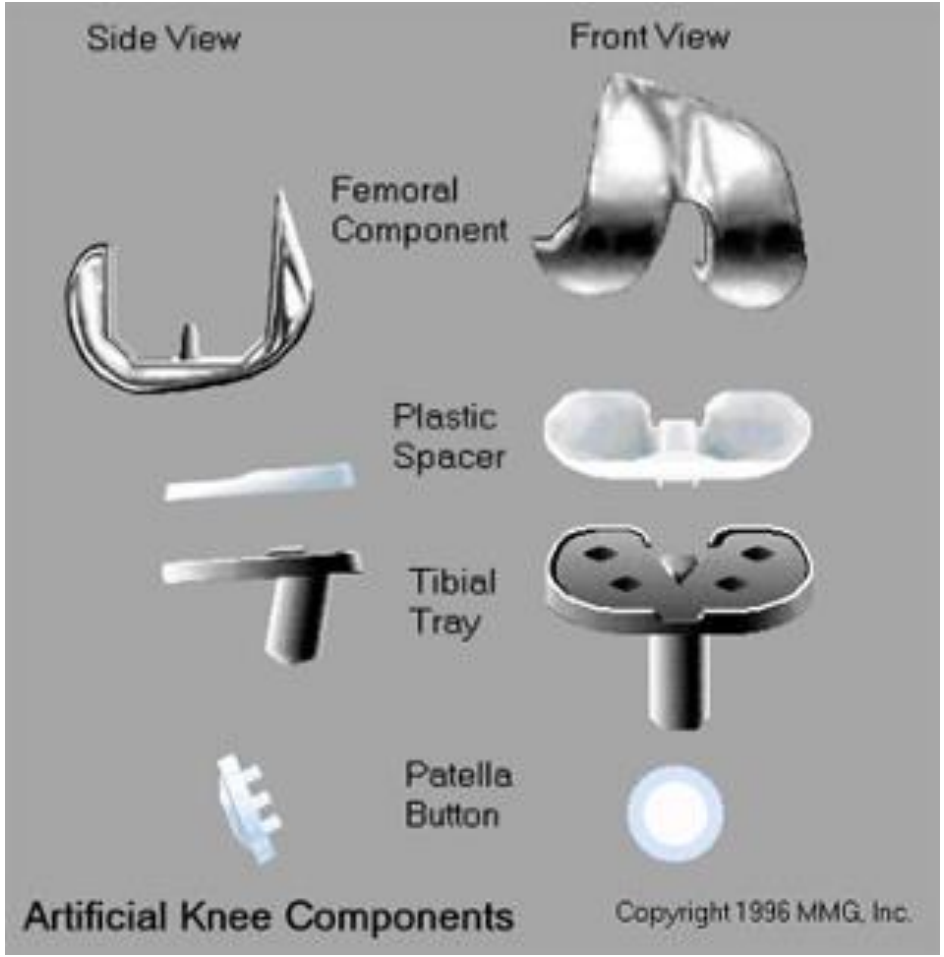
600 Bed Teaching Hospital

25 - 30 % Immigrants

10 % patients who had their Primary Joint Arthroplasty outside UK

Not able to recognize the Manufacturer (make & Mode) type of Knee or Hip Replacement (Arthroplasty)





Implant Identification: Key step of pre-op planning

Gold standard of Implant Identification : Barcode labels

Orthopaedic Implant (OI) ID

Instagram

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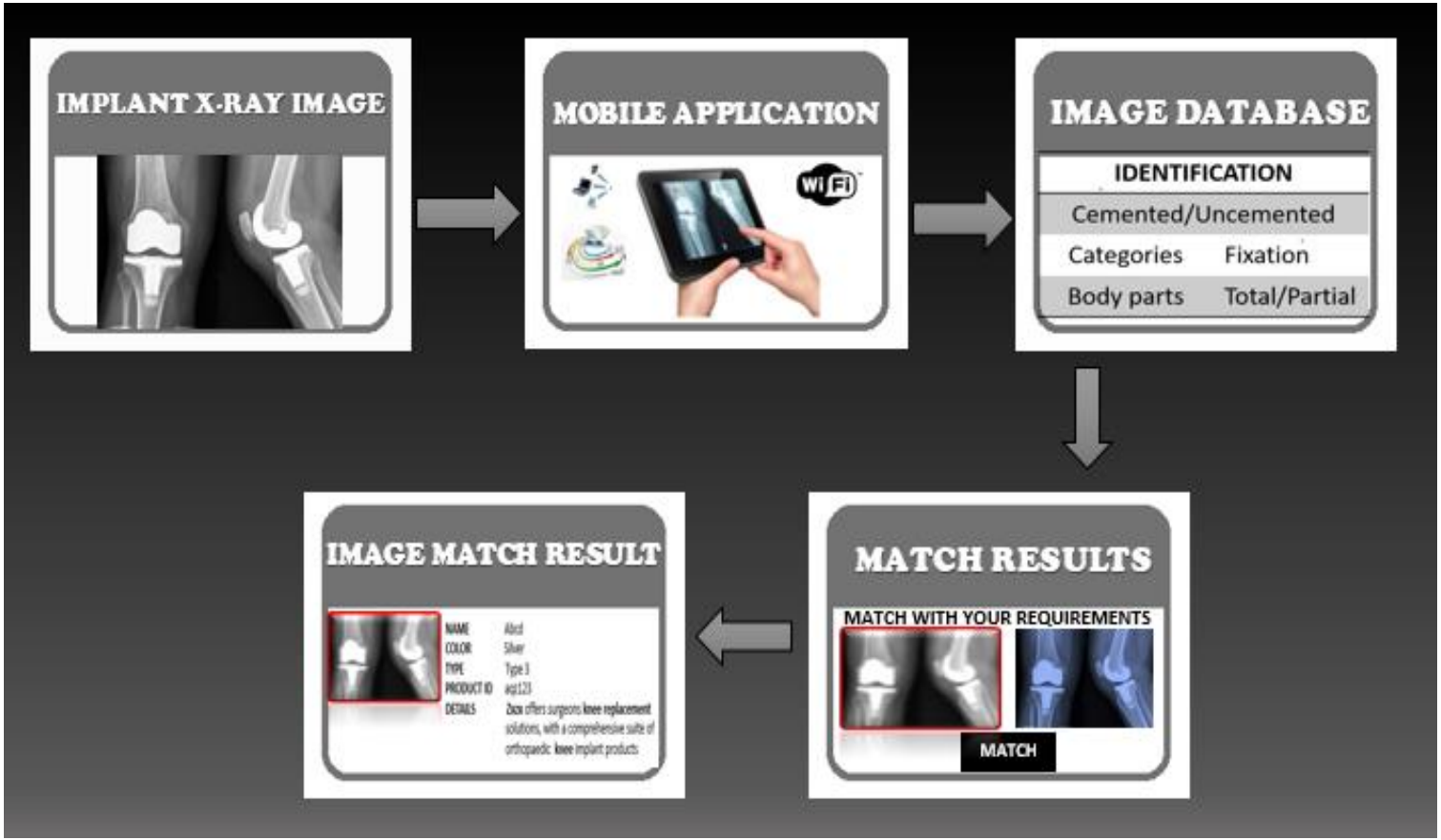
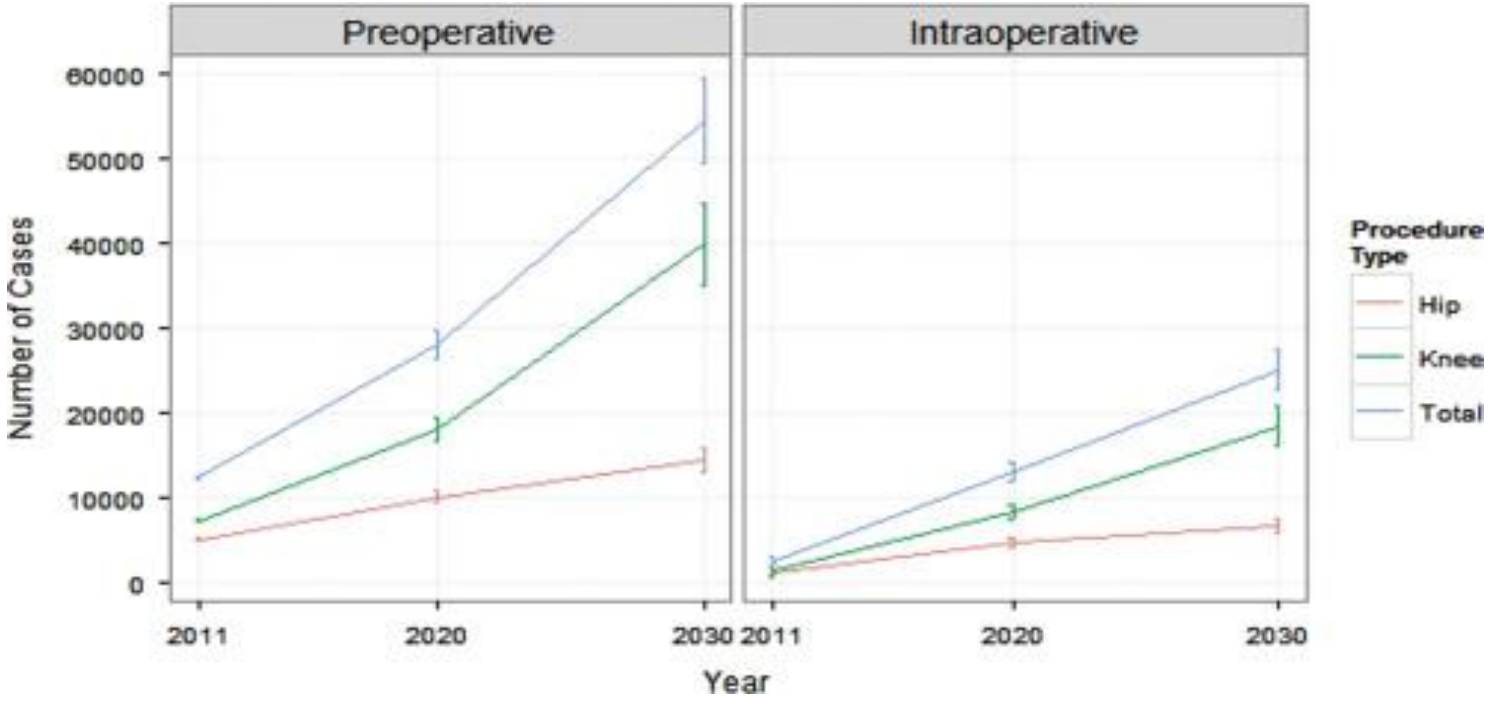


National projections of time, cost and failure in implantable device identification: Consideration of unique device identification use
Healthc (Amst) 2015. N Wilson et al .



Significant time, cost and inability to identify failed implants

- 87% of surgeons reported having this problem
- Median surgeon identification time was 30 min.
- 10% of implants could not be identified pre-operatively.
- 2% could not be identified intra-operatively.

www. whichorthopaedicimplant.com

WHICH? orthopaedic implant

Home | About | Identify | Implants | Help | Education | IIIMPRO – Implant Identification | Login | Register | Contact

Welcome

WhichOrthopaedicImplant.com is a searchable orthopaedic implant database for identification of orthopaedic devices. The website has been established as a *free reference*.

We are working to collect a comprehensive orthopaedic implant database of implant radiographs to assist orthopaedic surgeons in identification of orthopaedic devices. The correct identification of orthopaedic devices is an important element of pre-operative planning which should facilitate implant extraction during revision arthroplasty.

If you have a revision arthroplasty case where the patient's implant is unfamiliar, then use our implant **search function** to limit the possibilities. Our database of implant radiographs is categorised by *shape characteristics* which can be determined from the implant radiograph, without prior knowledge of the implant:

- Is the stem tapered or rounded ?
- Does it have a collar ?
- How many holes or insertion slots ?
- Convex or concave curvature ?
- Etc...

By answering some of these questions, you can filter the implant radiographs in our database down to a smaller sample to compare against your patient's implant radiograph. Our tutorial pages provide further explanation.

Alternatively if you know the orthopaedic implant in question then you can access specific **implant posts** which contain technical information and advice for planning revision arthroplasty.

Bear with us: This site has just been launched but we hope to increase the number of orthopaedic devices in the orthopaedic implant database, thereby offering progressive functionality. If you can see an opportunity to assist us in improving our database of implant radiographs then please do so.

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Our Database

Total Labelled 13349 [Make -93 | Model -353]

Knee – 6815 [Make – 22 | Model – 81]

Hip – 1921 [Make – 17 | Model – 87]

Shoulder – 1155 [Make – 20 | Model – 60]

Wrist – 277 [Make – 06 | Model – 10]

Foot and Ankle – 421 [Make – 11 | Model – 14]

Elbow – 50 [Make – 06 | Model – 13]

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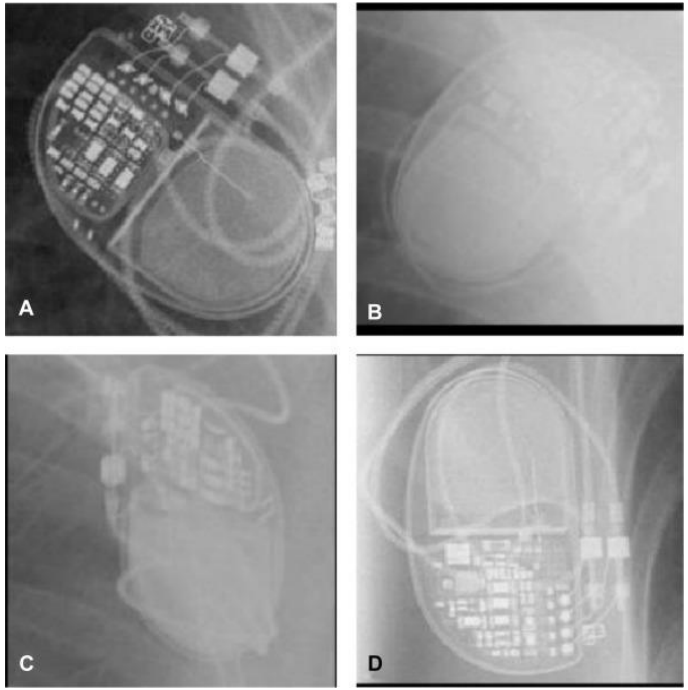
Cardiac Rhythm Device Identification Using Neural Networks

Department of Cardiology, National Heart and Lung Institute, Imperial College London,[b]Department of Cardiology, UCL [c]Department of Computing, Imperial College UK



Radiology: Artificial Intelligence

AI IN BRIEF

Automated Identification of Orthopedic Implants on Radiographs Using Deep Learning

Ravi Patel, MB, BChir, MA (Cantab) • *Elizabeth H. E. Thong, MBBS, BSc* • *Vineet Batta, FRCS(Orth), MBBS* • *Anil Anthony Bharath, PhD, BEng, FIET* • *Darrel Francis, FRCP, MD, MRCP, MB, BChir, MA (Cantab)* • *James Howard, MRCP, MB, BChir, MA (Cantab)*

From the Faculty of Medicine, Imperial College Healthcare NHS Trust, London, England (R.P., E.H.E.T., D.F., J.H.); Department of Bioengineering, Imperial College London, Level 2, Faculty Building, South Kensington Campus, London SW7 2AZ, England (R.P., A.A.B.); and Department of Orthopaedic Surgery, Luton and Dunstable University Hospital, Luton, England (V.B.). Received August 1, 2020; revision requested September 25; revision received February 21; accepted March 1. **Address correspondence to** R.P. (e-mail: *ravi-patel@doctors.org.uk*).

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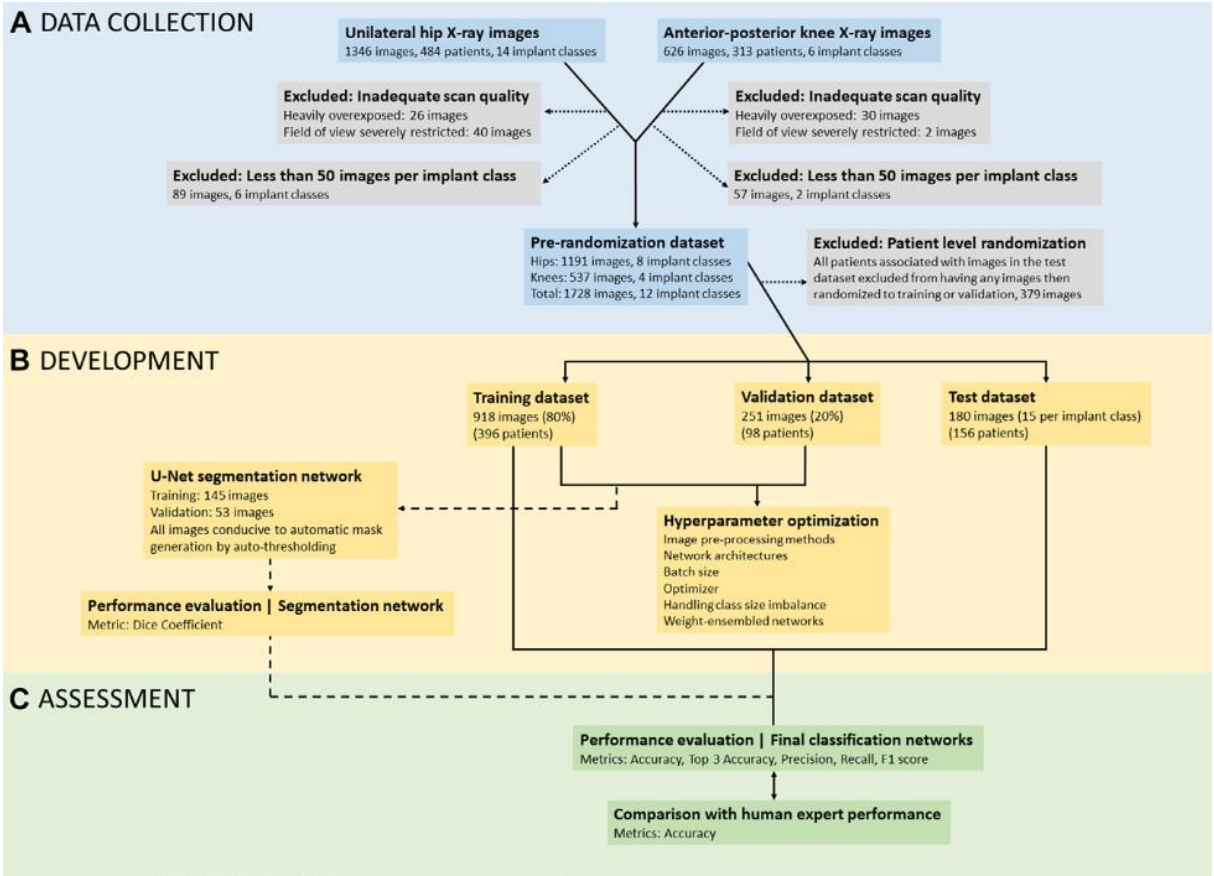
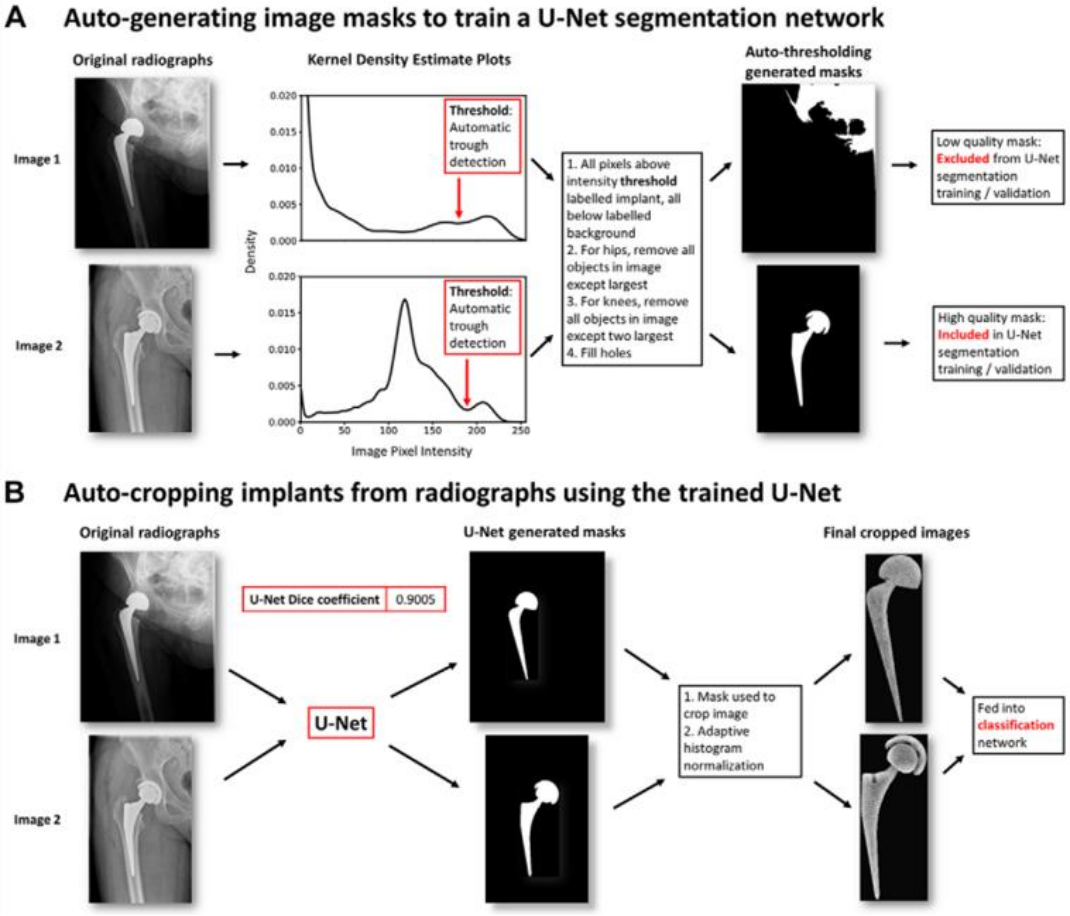
Conflicts of interest are listed at the end of this article.

Radiology: Artificial Intelligence 2021; 3(4):e200183 • https://doi.org/10.1148/ryai.2021200183 • Content codes: AI MK

Study Structure



Automated cropping of OI radiographs



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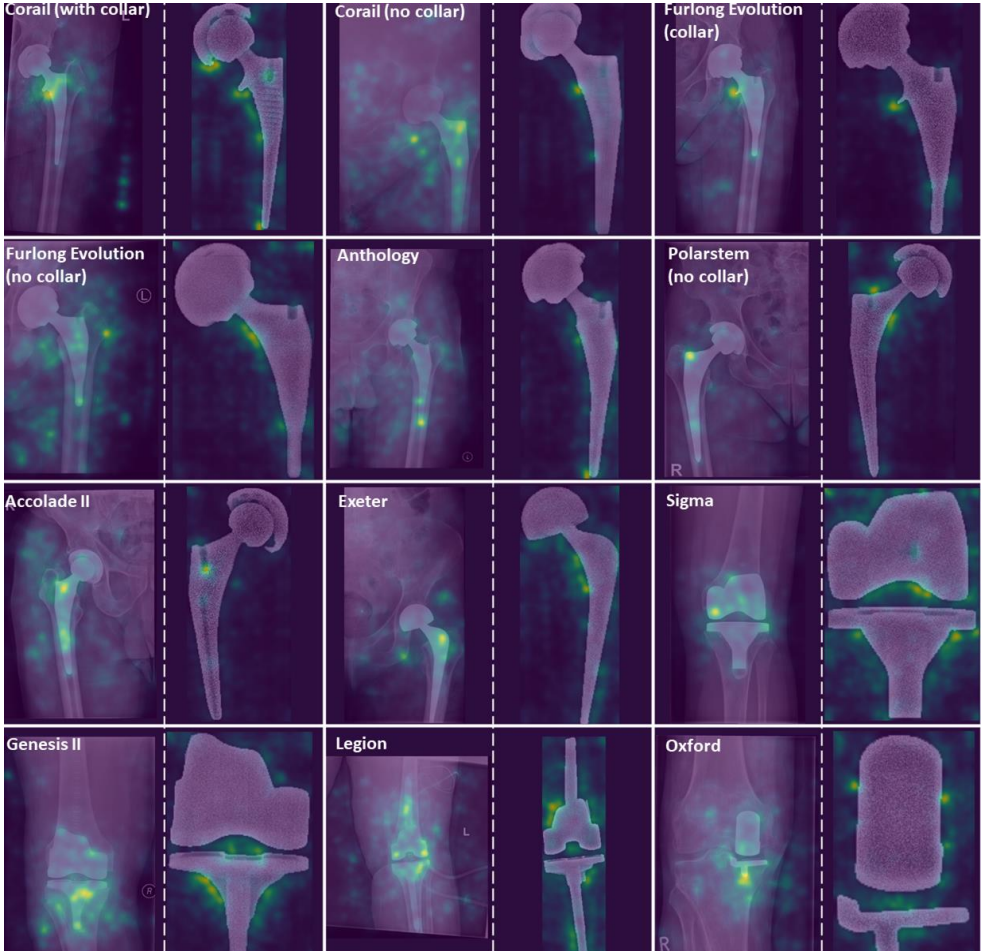
Distribution of Implant model design

Joint	Manufacturer	Model	Number	Higher quality test data example	Lower quality test data example
Hip	Depuy-Synthes	Corail (with collar)	189		
		Corail (no collar)	216		
	JRI Orthopaedics	Furlong Evolution (with collar)	95		
		Furlong Evolution (no collar)	65		
	Smith & Nephew	Anthology	156		
		Polarstem (no collar)	113		
	Stryker	Accolade II	86		
		Exeter	271		
Knee	Depuy-Synthes	Sigma	156		
	Smith & Nephew	Genesis II	206		
		Legion	74		
	Zimmer-Biomet	Oxford	101		

Saliency maps of EfficientNet(left) and U-Net-EfficientNet(right)



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Performance evaluation of final classification networks

Structure (see Fig. 3)	Network architectures	Trainable parameters (millions)	Number of training epochs	Accuracy	Top 3 Accuracy
Structure 1 Single classification network on original images	InceptionV3	21.8	80	95.0%	100%
	Xception	20.8	40	90.0%	97.8%
	ResNet50V2	23.6	120	88.9%	98.3%
	DenseNet121	7.0	120	88.3%	99.4%
	InceptionResNetV2	54.3	50	87.2%	97.8%
	NASNetMobile	4.3	40	32.2%	52.8%
	MobileNetV2	2.3	40	16.7%	38.3%
Structure 2 Single classification network on segmented images	Unet-InceptionV3	21.8	80	97.8%	98.9%
	Unet-Xception	20.8	40	96.7%	98.3%
Structure 3 Two 1:1 weight-ensembled classification networks with original and segmented inputs	Unet-Xception + InceptionV3			99.4%	100%
	Unet-InceptionV3 + InceptionV3			98.3%	99.4%
	Unet-Xception + Xception			97.2%	100%

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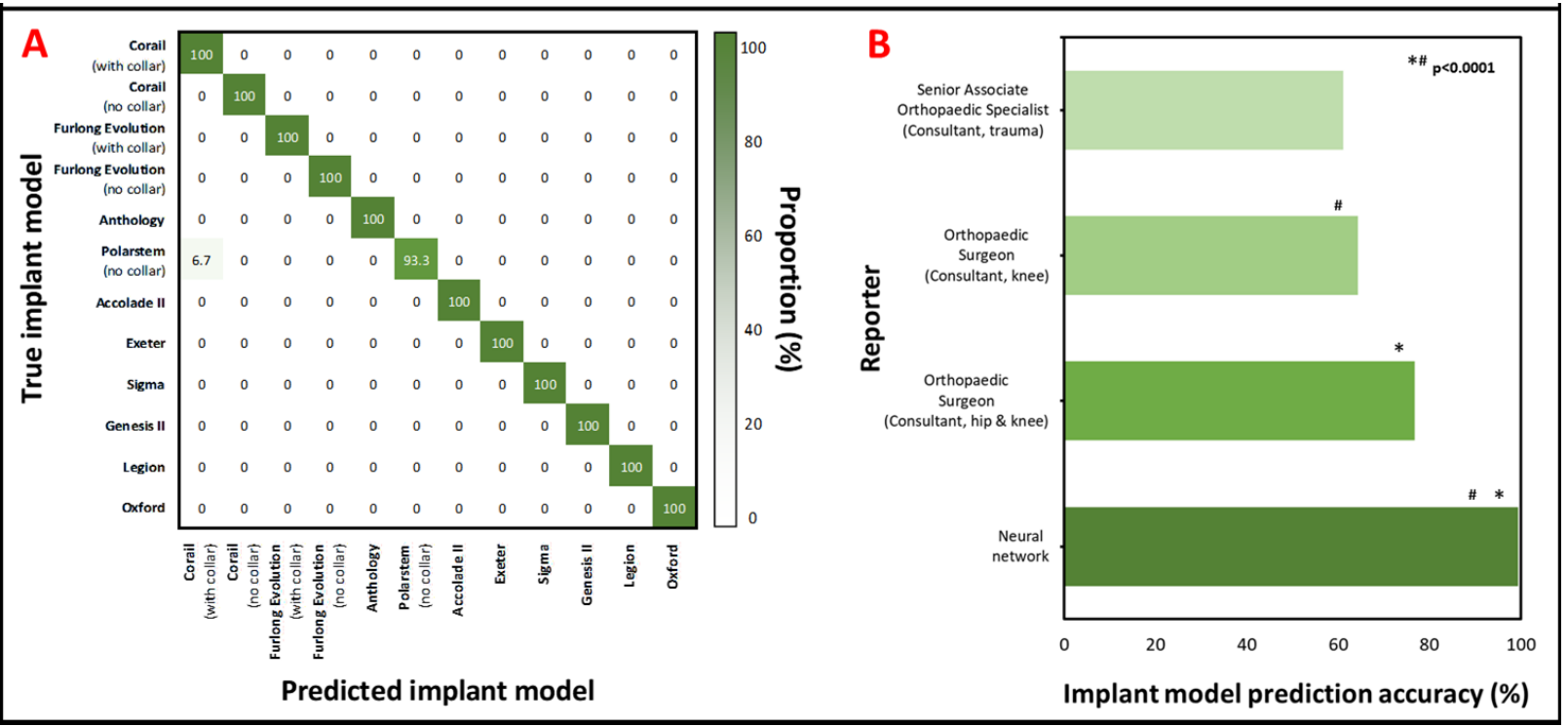
Best performing network (A) and comparison with human expert performance (B)



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Dissemination

Published Manuscript:

1. Patel, Ravi, et al. "Automated identification of orthopedic implants on radiographs using deep learning." *Radiology: Artificial Intelligence* 3.4 (2021): e200183
2. Belete, Samuel C., Vineet Batta, and Holger Kunz. "Automated classification of total knee replacement prosthesis on plain film radiograph using a deep convolutional neural network." *Informatics in Medicine Unlocked* 25 (2021): 100669
3. R. Patil et al. "Supra-human orthopaedic implant identification in radiographs using deep learning", Imperial College Healthcare NHS Trust, Faculty of Medicine, London, UK. BOA Virtual Congress 2020.
4. Sukkrit Sharma, Dr. Vineet Batta, et al. “Knee Implant Identification by Fine tuning Deep Learning Models “, In press.

Forthcoming Manuscript

1. “Automatic Identification of Make and Model of Ankle Implants using Artificial Intelligence” ICECCT, 2023
2. “Automated Identification of Make and Model of Total Wrist Replacement Implants using Deep Learning" MVML, 2023.
3. " Identification of knee prostheses from lateral radiographs using deep learning techniques“ CIST, 2023

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Orthopaedic Implant List

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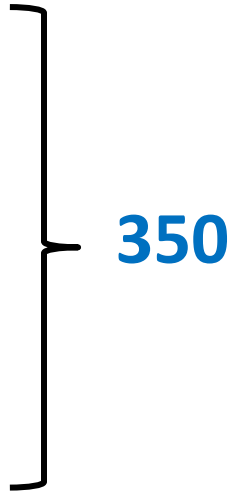
KNEE

- Total Knee Replacement
- Unicondylar
- Bicompartmental
- Patello Femoral
- Revision Knee Replacement
- Other

300

HIP

- Total Hip Replacement
- Hemi Arthroplasty
- Resurfacing
- Revision
- Bipolar
- Other



SHOULDER

- Total Shoulder Replacement
- Partial Shoulder Replacement
- Reverse Shoulder Replacement
- OTHER

154

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FOOT AND ANKLE

- Total Ankle Replacement
- Great Toe Arthroplasty
- Revision Ankle Replacement
- Other

139

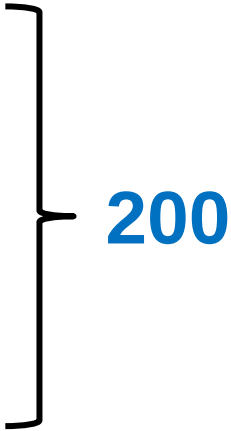
HAND, WRIST AND ELBOW

- Total Wrist Replacement
- Ulnar Head Replacement
- Proximal Interphalangeal Joint Replacement
- Elbow
  - Total Elbow Arthroplasty
  - Hemi Elbow Arthroplasty
  - Radiocapitellar
  - Distal Humeral
  - Ulnohumeral Distraction & Interpositional Arthroplasty
  - Olecranon Fossa Debridement
  - Radial Head Arthroplasty

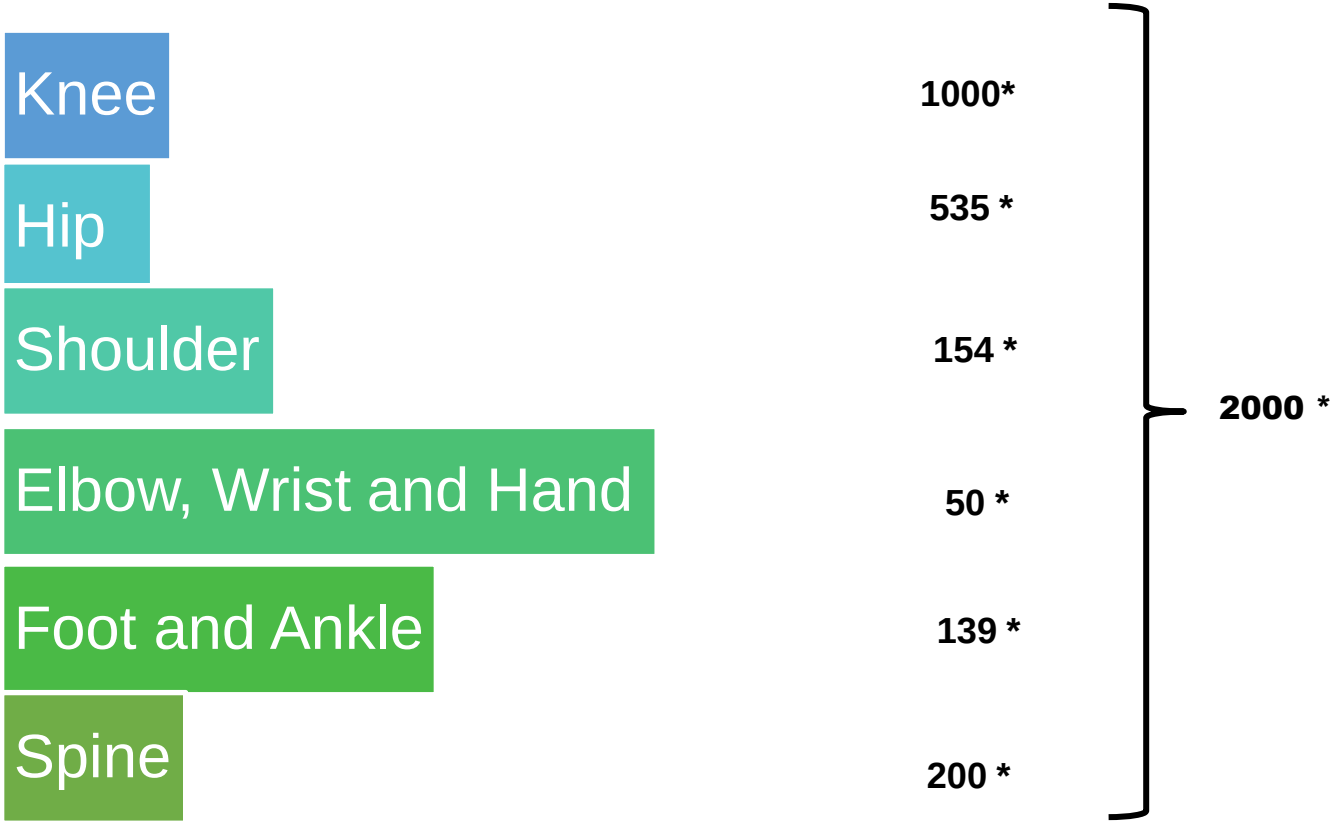
50

SPINE

- TOTAL DISC REPLACEMENT
- DISC NUCLEUS REPLACEMENT
- LUMBAR DISC REPLACEMENT
- OTHER



SUMMARY OF ORTHOPAEDIC LIST



* appx

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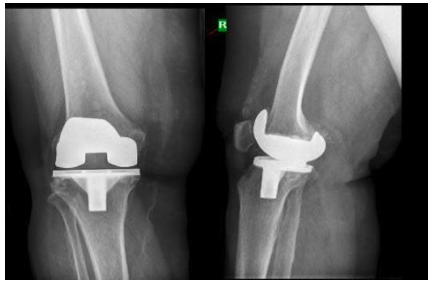
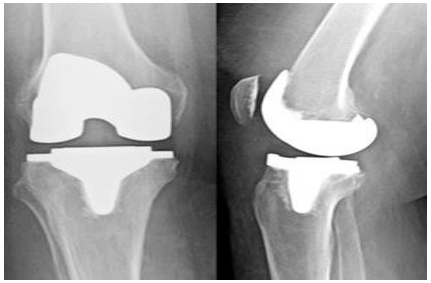
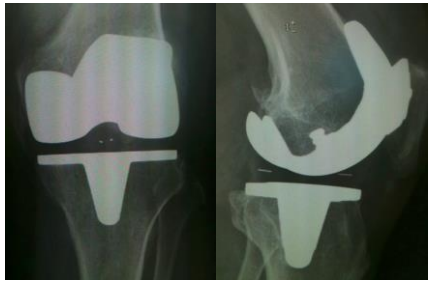
Knee Arthroplasty



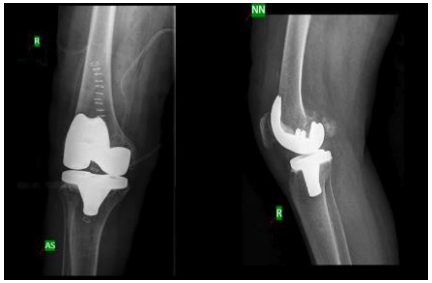
DePuy- PFC Sigma



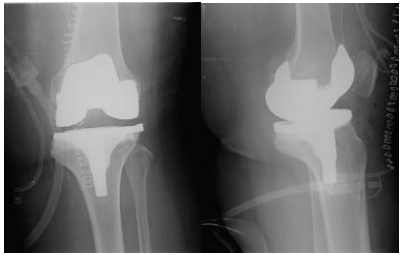
DePuy - Attune



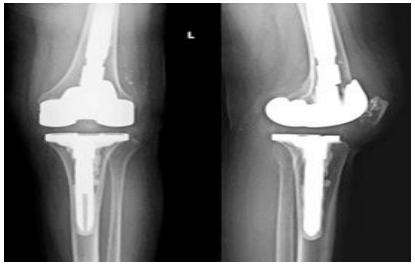
Depuy - LCS



Meril Maxx - Freedom



Smith & Nephew - Genesis II

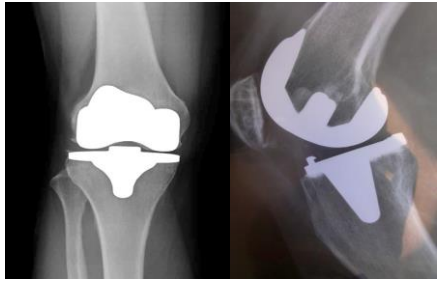


Smith & Nephew - Legion

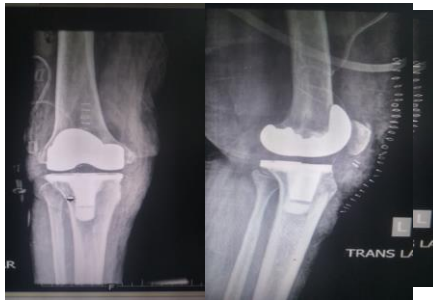
Smith & Nephew - Journey II

Stryker - Triathlon

Stryker - Scorpio



Stryker - Duracon



Zimmer - Nexgen

Biomet- LPS

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Hip Arthroplasty

Stryker Accolade II

Stryker Exeter

Biomet - Taperloc

Biomet - Arcos

DePuy ASR Cup & Summit Stem

Howmedica Cup & Accolade Stem

Stryker - Osteonics Secure-Fit HA

Smith & Nephew Optifix Modular Stem

Smith & Nephew Reflection Cup & Spectron Stem

Smith & Nephew SP-3 Cup

Smith & Nephew SP3 Cup & Synergy Stem

BBraun Exc
(Cemented)

Elbow Arthroplasty

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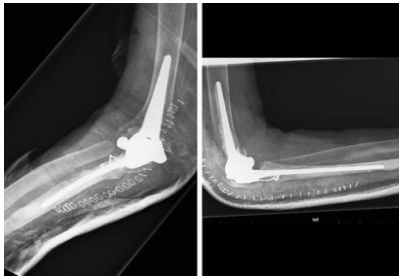
Zimmer - Coonrad/Morrey elbow

Zimmer - Nexel total elbow

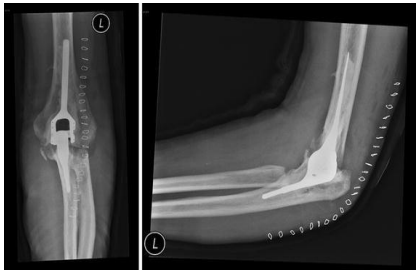


Zimmer - GSB III Elbow

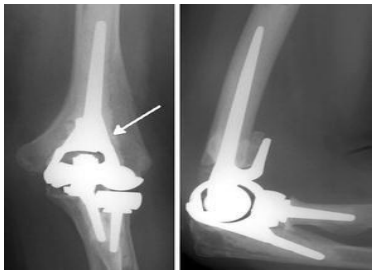
Biomet - Discovery elbow

Stryker - Kudo type-5 prosthesis

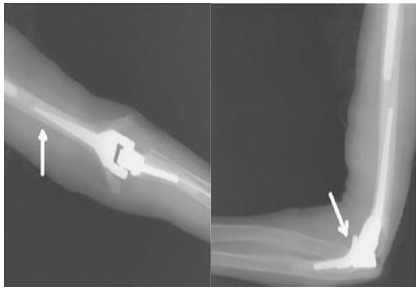
Biomet - iBP Total Elbow System



Implant Cast - NESimplavit elbow



Tornier - Latitude Elbow



Stryker - Solar elbow

Stryker - Souter–Strathclyde total elbow

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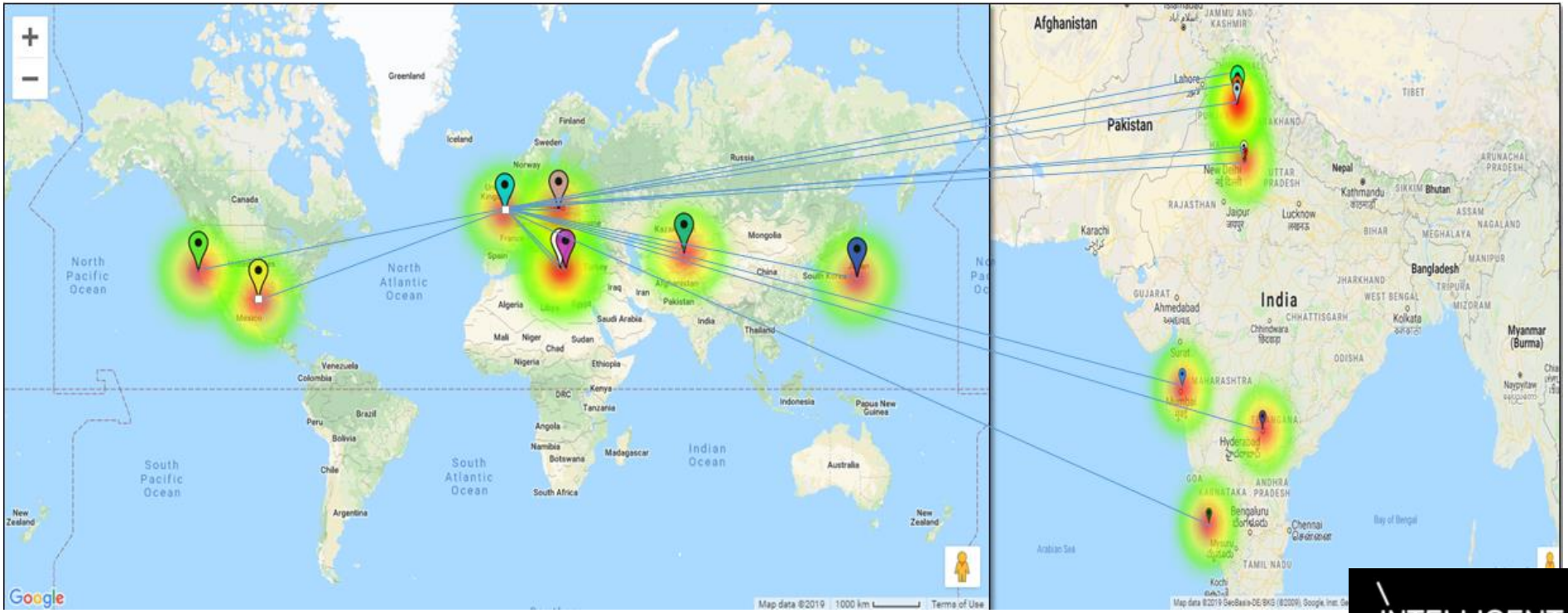
Collaborating Hospitals / Universities



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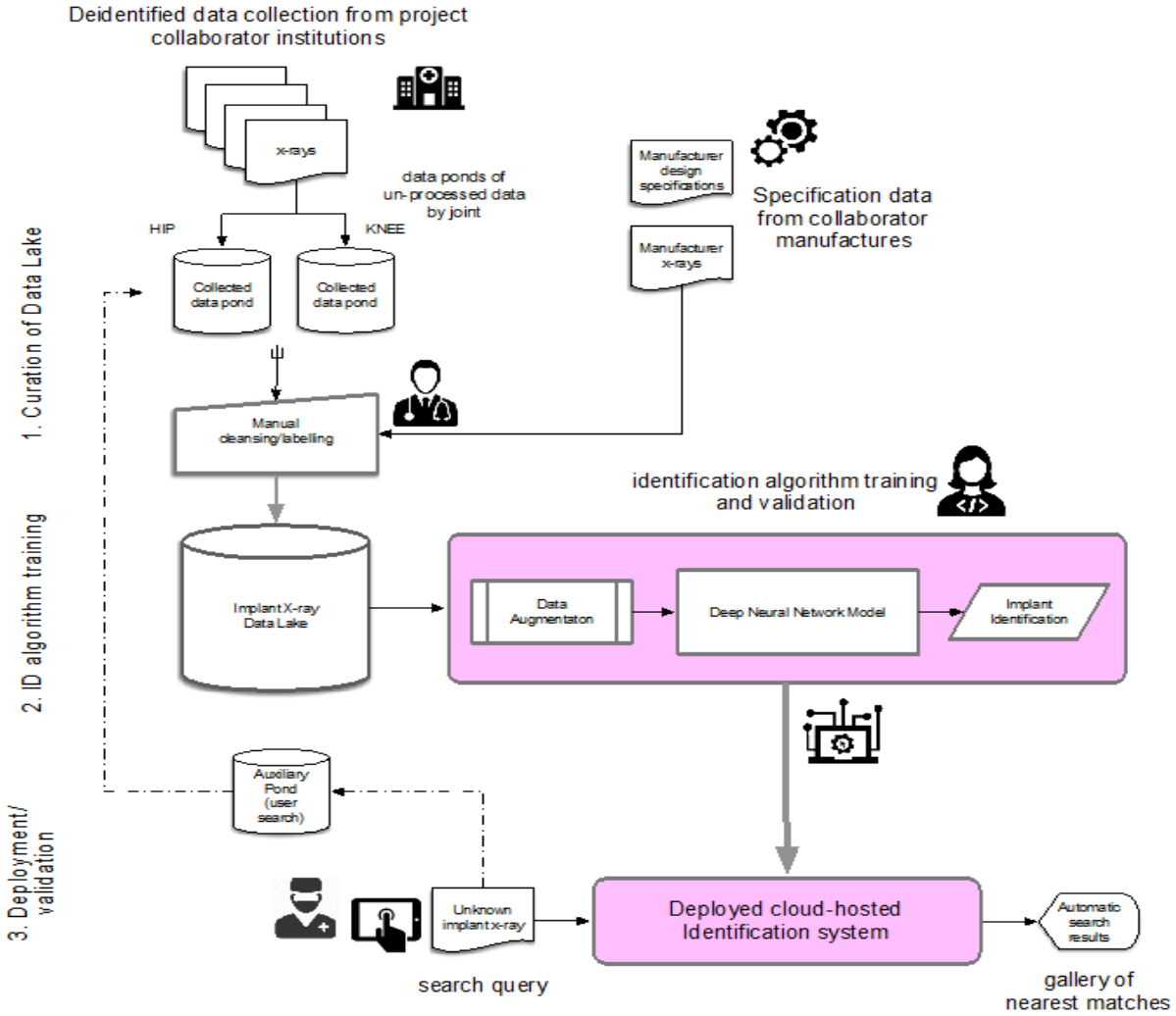
Period	Issue/complication	Impact	Monetary estimate (per revision)
Pre-operative	• Delay in identifying implant because of lack of access to patient notes • Delay in scheduling operation • Problems in sourcing correct spare parts	• Extra technician, surgical time in identification • Delay to operation and potential patient discomfort • Need to hold stocks of rarely used components	Bed costs saving £375/day; foreign implants £1500; technician salary 0.5 day/case
Intra-operative	• None or incorrect replacement parts available • Re-use of worn implant components • Surgical complications, e.g. greater blood-loss, greater use of anaesthesia	• Lengthened surgery • Greater use of surgical time and support	£32 per minute; ~£1000 pounds per surgery
Post-Operative	• Longer hospital stays • Remedial/follow-up surgery	• Longer patient recovery • Potential relapse of condition of further failure of implant • Need for re-revision surgery	2 days extra in hospital = £600-£3,000 pounds bed time; drug usage costs; re- revision surgery - 2x costs
		Total estimated perannum@10% re-revision rate.	5000 cases x £6000 = £30M


Deidentified data collection from project collaborator institutions
x-rays
data ponds of un-processed data by joint
HIP
KNEE
Collected data pond
Collected data pond
Manufacturer design specifications
Manufacturer x-rays
Specification data from collaborator manufactures
1. Curation of Data Lake
Manual cleansing/labelling
identification algorithm training and validation
2. ID algorithm training
Implant X-ray Data Lake
Data Augmentaton
Deep Neural Network Model
Implant Identification
3. Deployment/ validation
Auxiliary Pond (user search)
Unknown implant x-ray
search query
Deployed cloud-hosted Identification system
Automatic search results
gallery of nearest matches

UDIs and GUDID

In 2014, the Food and Drug Administration (FDA) issued a new rule requiring manufacturers to label medical devices with

- unique device identifiers (UDIs) and
- Publicly accessible Global Unique Device Identifier Database (GUDID)

Problem Statement

- Around 7 million adults living with some form of Orthopaedic implant in USA[1]

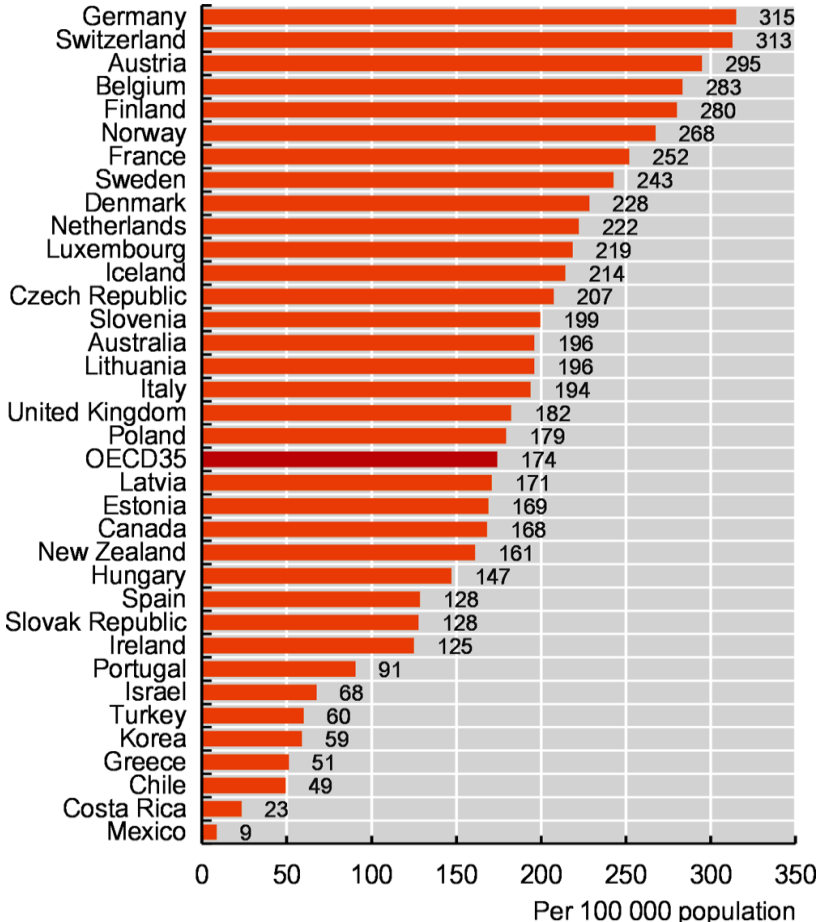
- Factors for Implant failure
  ➔ Infection, instability, stiffness, wear and tear,loosening, and fractures

- Any Implant average life span 10 -15 years

- The surgeon requires the primary surgery's implant model to plan revision surgery, but that info is unavailable.

- Need to order the correct spare from right company, delay treatment, and
  to the patients, which can be prevented with our proposed tool

Hip replacement surgery, 2019 (or nearest year)



3.6 Billion X-rays performed every year globally

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- About 2 - 8 % have an Implantable medical device
- 1st all orthopaedic Implants
- Identify all Implantable Medical devices

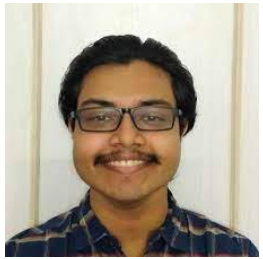
Minimizing training data required to Identify the make & model of Orthopaedic Implants

Method:

1. To create a 20-class classification model spanning the hip, knee and shoulder wherein, the data has been sourced from multiple centres.
2. Develop a few shot problem (where every class possesses less than 10 Xray's) based on a meta-learning neural network in order to build on the sustainability aspects of the problem.

Initial Result :

1. Achieved state-of-the-art precision scores (90%) for 10 implant class models with only 30 implant per class (as opposed to the industry average of 100).
2. Identified challenging classes to classify.



Soumya Snigdha Kundu
M.Sc. ML at QMUL
Incoming ML PhD at King's College London

Co- Supervisor: Mr. Vineet Batta
Luton and Dunstable Univ. Hospital

Supervisor: Prof. Gregory Slabaugh
Professor of Computer Vision and AI and Director of the Digital Environment Research Institute (DERI) at QMUL.

Thank You

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Breaking down the barriers between tech and healthcare