Value-based Validation of AI in Medical Imaging
The use of Artificial Intelligence and Machine Learning in health sector offers strong potential to redesign healthcare delivery. Dubai Health Authority and Agfa HealthCare recognized the potential of Machine Learning Algorithms and AI enabled workflows in medical imaging three years ago. With a strategic goal for workflow automation and fast access to diagnostic imaging results, an approach to enable Augmented Intelligence in medical imaging was devised to consider application of AI in Chest X-Ray screening.

WHAT IS AUGMENTED INTELLIGENCE?

Augmented Intelligence is the intersection of machine learning and advanced applications, where clinical knowledge and medical data converge on a single platform. The potential benefits of Augmented Intelligence are realized when it is used in the context of workflows and systems that healthcare practitioners operate and interact with. Unlike Artificial Intelligence, which tries to replicate human intelligence, Augmented Intelligence works with and amplifies human intelligence.

FIRST VALUE-BASED AI VALIDATION IN DUBAI, UAE:

At global Thought Leadership industry events and conferences like Dubai Health Forum 2018, Dubai’s leadership, physician community, academia, young graduates and industry leaders interested in the intersection of machine learning, and medicine, are discussing application of AI into the practice of medicine and its role in personalized care delivery.

Dubai Health Authority (DHA) and Agfa HealthCare signed a Memorandum of Understanding (MoU) at the Arab Health Conference 2018. The MoU has led to the first Augmented Intelligence (AI) validation in the United Arab Emirates (UAE) based on Chest X-Ray.

This government-industry MoU will enable key benefits of Artificial Intelligence, and will support the Dubai Health Authority’s goal of incorporating the latest technological advancements in the medical field for improved efficiencies and enhanced patient-centric care.
Agfa HealthCare’s innovative approach in the field of medical imaging IT is well recognized. To facilitate early adoption of AI in health sector, Dubai Health Authority and Agfa HealthCare began exploring following factors when it comes to AI enabled workflows in medical imaging:

1. ENTERPRISE IMAGING STRATEGY
   Building medical imaging data lake for machine learning

2. RULES-BASED WORKFLOW AUTOMATION
   Removing non-essential tasks from experts

3. MULTIDISCIPLINARY VISUAL COLLABORATION
   Enabling cross specialty real-time communication

4. DIAGNOSTIC INTELLIGENCE
   AI embedded workflows to verify and validate AI accuracy

5. PERSONALIZED MEDICINE
   Co-relation of medical imaging and clinical records

Value-based care is all about providing cost effective quality care and helping improve outcomes. With this approach in mind, Dubai Health Authority and Agfa HealthCare began exploring the use of AI technology across 20 Medical Fitness Centers in Dubai, in 2015. Based on current workflow gaps and the need to improve turn-around times, it was decided to validate AI enabled automated Chest X-Ray screening workflow at the medical fitness centers.

The DHA provided Agfa HealthCare anonymized Chest X-Rays samples, half of which were categorized as Normal X-Rays, and remaining half with Tuberculosis findings based on lab confirmation.

Agfa HealthCare and VRVis Vienna analyzed these anonymized X-Rays between 2015-2016, and developed a workflow concept with Machine Learning Algorithm.

After the development and lab testing phase, Agfa HealthCare and Dubai Health Authority devised an onsite validation framework to test the AI algorithm for accuracy in Dubai. An onsite validation and testing workflow was designed to assure evidence was documented appropriately.

Two Radiologists were assigned by DHA, during Phase One onsite validation, to validate AI Algorithm generated results, and provided feedback if they agree or disagree with the AI Algorithm findings.

Upon completion of Phase One onsite validation early January 2018, the AI Algorithm Validation workflow designed by Agfa HealthCare correctly flagged Tuberculosis findings with 90% accuracy, based on Chest X-Ray findings.

After completion of Phase One onsite validation in January 2018, the AI Algorithm was retrained and deployed again at one of the Medical Fitness Centers in Dubai.

Phase Two onsite validation is currently in progress (February 2018), the AI Algorithm’s sensitivity improved to 95% after completion of Phase One onsite validation, the goal now is to further validate AI Chest X-Ray Algorithm with input from DHA Radiologists.
PRELIMINARY RESULTS SUMMARY:

At the time of publication of this report (February 2018), over 4,500 Chest X-Rays have been analyzed by the AI Algorithm currently deployed at one of the DHA Medical Fitness Centers in Dubai.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Phase One (2017)</th>
<th>Phase Two (2018: re-trained algorithm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity: (TB Positive)</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Specificity: (True Negative)</td>
<td>55%-70%</td>
<td>70%-75%</td>
</tr>
<tr>
<td>AUC*</td>
<td>0.911 (A)</td>
<td>0.923 (A)</td>
</tr>
</tbody>
</table>

DEFINITIONS

SENSITIVITY
Proportion of TB positive images (i.e. having TB) correctly labeled as positive

SPECIFICITY
Proportion of TB negative images (i.e. not having TB) correctly labeled as negative

ROC CURVE:
Each point on the ROC curve represents a sensitivity/specificity pair corresponding to a particular decision threshold. The area under the ROC curve (AUC) is a measure of how well a parameter can distinguish between two diagnostic groups (diseased/normal).

*Rough guide for classifying the accuracy using a traditional academic point system:

- 0.90-1 = excellent (A)
- 0.80-0.90 = good (B)
- 0.70-0.80 = fair (C)
- 0.60-0.70 = poor (D)
- 0.50-0.60 = fail (F)
“Based on the analysis of results so far, and how the AI Algorithm is performing, we will be able to significantly improve our reporting workflows. Currently, due to high exam volumes, standard reports can take up to seven days before they get signed off. With AI technology, cases that are flagged for a disease like Tuberculosis would get followed up on the same day.”

Dr. ElTag M. Ibrahim Mudawi
Specialist Radiologist
Medical Fitness Center
Dubai Health Authority

“We perform nearly 5000 Chest X-Rays every day across the 20 Medical Fitness Centers in Dubai. We want to improve turn-around times, accommodate more exams, increase volume and capacity, and ensure we spend more time in clinical review instead of manual work of sorting out daily exam worklists. That’s where AI will help us to be more productive and help us serve our communities better and improve client satisfaction”.

Dr. Loai Osman Said
Specialist Radiologist
Medical Fitness Center
Dubai Health Authority
Agfa HealthCare approach - The Enterprise Imaging Solution to enable Task-based rules powered by AI and Machine Learning

- Improved turn around times
- Reports available in minutes
- Patient satisfaction
- Automated reports
- Fast image analysis
We reached out to senior Radiologists, Academics, Clinical Leaders, Department Chairs, Operations Directors, and Industry Analysts, and have included their responses regarding the Chest XRay AI Algorithm Validation project currently underway in Dubai.

ENTERPRISE IMAGING STRATEGY - BUILDING AN IMAGING DATA LAKE

DHA has 20 medical fitness centers across the emirate of Dubai for issuance and renewal of visas. DHA is currently validating the use of AI technology with Agfa HealthCare and plans to implement this technology across a few medical fitness centers for continuing validation. Then, the DHA will assess the feasibility of expanding this technology across all of its 20 medical fitness centers. The total number of people who visited the DHA run medical fitness centers during 2017 for new and renewal visas were 2,126,066. A medical fitness test is a mandatory requirement for all expats in the UAE. It is required for a residency, employment or education visa.

Keeping in mind the recent advancements in medical imaging, and as radiology moves out of the traditional departments to primary care and becomes mobile; the traditional departmental PACS approach created not only clinical collaboration challenges but Information Technology infrastructure and integration issues as well. Dubai Health Authority recognized the significance of Enterprise Imaging strategy and introduced medical imaging consolidation across its network of hospitals and medical imaging centers earlier on, and began building the foundation for a medical imaging AI strategy. Agfa HealthCare is the provider of Enterprise Imaging Solution at the Medical Fitness Centers in Dubai.

“At the DHA, we are keen to utilize technology after comprehensive evaluation and looking into how the technology fits into the nuances of the health sector in Dubai. We will be utilizing AI technology in the health sector since it has a strong potential to redesign healthcare completely – and for the better. As part of the collaboration, we will work together to establish an enterprise imaging strategy for the DHA to enable multi-speciality medical imaging consolidation. We will establish a framework of Artificial Intelligence workflow to augment radiology imaging, including in the area of detecting diseases and we will collaborate to validate machine-learning algorithms in development.”

Dr. Mohammad Al Redha
Director
The Executive Office for Organizational Transformation
Dubai Health Authority
RULES-BASED WORKFLOW AUTOMATION

With the goal to validate accuracy of the Chest X-Ray AI Algorithm, Radiologists at the assigned Medical Fitness Center in Dubai have been providing feedback if they agree or disagree with the results being provided by the AI Algorithm, thanks to an automated workflow created in their PACS workstation. Upon completion of first phase of onsite validation early January 2018, over 4,500 Chest X-Rays were processed by the AI Algorithm.

Dr. ElTag M. Ibrahim Mudawi
Specialist Radiologist - Medical Fitness Center
Dubai Health Authority

“One of the challenges we have is the manual review of thousands of Chest X-Rays every day to find suspected cases. With AI embedded into our workflow, we will be able to prioritize our exam reviews much faster, and initiate review on cases flagged by AI technology much faster instead of waiting for days due to huge exam backlog”

MULTIDISCIPLINARY VISUAL COLLABORATION

Technology should enable cross-departmental real-time communication and specialist collaboration, to help improve care-pathways. Agfa HealthCare’s modern Enterprise Imaging platform will not only help remove traditional barriers to medical image exchange across the 20 Medical Fitness Centers, but will also help enable cross site radiologists collaboration. With AI embedded into Chest X-Ray screening workflows, DHA will benefit by prioritizing some of the tasks, including report creation, which currently can take up to a week. With AI enabled notifications, Radiologists across multiple DHA sites would be able to receive prioritized task notifications and leverage real-time chat and communication features of Enterprise Imaging to discuss and review cases that require further observation and immediate follow up.

Maisa Al Bustani
Director of Medical Fitness
Dubai Health Authority

“With the implementation of this technology, we will be able to greatly enhance efficiencies and workflow management as doctors will now be able to accommodate more reports. The technology will generate automated reports that the doctor will confirm. This will make screening and evaluation more efficient; it will significantly reduce the time taken to receive reports and thus will speed up the overall process”
DISSEMINATE DIAGNOSTIC INTELLIGENCE WITH AI

As we enable multidisciplinary consolidation and collaboration, the power of a consolidated platform results in creation of a vast data lake, ready for analysis by radiologists, diagnosticians, researchers and academics to help improve quality of care by better understanding disease and population health data. This will help DHA progress from Descriptive to Predictive Analytics models to improve early detection of diseases, and introduce care plan models that help enforce and improve patient engagement and compliance.

During discussions with senior Radiologists and Diagnosticians in Dubai, there was consensus regarding the clinical application of AI to help address screening challenges associated with pressing healthcare problems that include Tuberculosis detection when it comes to Medical Fitness Center screening programs.

Dr. Bassam Mahboub
Consultant Pulmonologist and Lead of Care Model Innovation
Dubai Health Authority

“As a physician, my perspective is that the use of this amazing technology will transform the way we practice medicine, I’m not worried about AI replacing physicians, and I can predict that physicians who know how to harness AI will replace those who don’t”

PERSONALIZED MEDICINE AND SMART APPLICATIONS

Care organizations and health authorities across the globe are faced with pressing population health challenges. Whether it comes to detecting cancers or chronic diseases, Machine Learning and Advanced Analytics will help improve radiologists and diagnosticians focus less on manual repetitive tasks and more on providing evidence based clinical input to help improve outcomes.

By leveraging AI to screen potential Tuberculosis cases out of several thousand Chest X-Rays every day, Radiologists at Medical Fitness Centers across DHA will be able to optimize a care coordination strategy for susceptible groups of the population that fall under similar clinical conditions. Currently, it requires Radiologists at the Medical Fitness Centers to go through thousands of X-Rays every day to manually prioritize suspected findings, and then flag these suspected findings for further review. With AI, this task may be automated and even incorporate standard report templates to enable fast report creation and improved turnaround times. That is what Radiologists at DHA Medical Fitness Centre in Dubai are validating with Agfa HealthCare.
We live in an era of value-based care and are now moving towards personalized care and precision medicine. Although precision medicine is still in its infancy, recent advancements in scientific research, information technology, medicine and public opinion provide an opportunity to enable its capabilities.

Precision Medicine and Value-based care align in the sense that both focus on improving patient outcomes. Precision medicine is not about creating treatment plans or new medical devices for each patient, but in fact precision medicine advocates personalizing care delivery to susceptible groups of populations who fall under a specific disease condition in order to promote better outcomes.

Where we go with AI in medical image analysis is evolving; it will definitely help the patients directly as clinicians will be better informed with evidence-based AI data and be able to tailor precise care for their patients.

“I am really honored to be a witness of Dubai Health Authority’s initiation of its journey towards transforming into a learning healthcare system by launching an AI-Based algorithm for detecting Chest diseases through scanning and analyzing Chest X-Rays. There is no doubt that adopting Artificial Intelligence which is a constituent part of DHA’s comprehensive Innovation & AI strategy will allow the organization to leapfrog its counterparts at both local and regional levels.

The long-lasting strategic partnership that DHA is enjoying with Agfa HealthCare has enabled our innovation and clinical teams to initiate a cutting edge AI use case in which we are able to demonstrate the beauty and the power of AI techniques. This exciting use case shrewdly utilized DHA’s enormous wealth of unstructured data (i.e. previously scanned and analyzed Chest X-Rays), the sincere efforts of our talented team of radiologists and the unmatched mathematical modelling and pattern recognition skills of Agfa HealthCare’s team of scientists at their R&D labs to come up with a well-trained machine learning algorithm for auto-detecting certain Chest diseases.

I am really impressed with this particular achievement for three main reasons: the adoption of such a solution certainly provides DHA with a platform that can easily off-spring many more use cases in the near future around Chest X-Ray exams, the smoothness of incorporating this AI-based solution into the medical fitness clinical workflows and processes, and finally the proven ROI that has already been captured in terms of cost-effectiveness/high-throughput of analyzed imaging exams. The latter will definitely increase the overall medical fitness service performance and thus ensures the service consumer satisfaction.”

Dr. Osama El Hassan
Head of eHealth, Health Data & Information Analysis Department
Dubai Health Authority
AGFA HEALTHCARE APPROACH
The Enterprise Imaging Solution
to enable Task-based rules powered by AI and Machine Learning

- Improved turn around times
- Reports available in minutes
- Improved patient satisfaction
- Automated reports
- Fast image analysis

**PHASE ONE**
- 2017
  - SENSITIVITY +: 90%
  - SPECIFICITY -: 55% - 70%
  - AUC: 0.911(A)
- **EXCELLENT**

**PHASE TWO**
- 2018
  - SENSITIVITY +: 95%
  - SPECIFICITY -: 70% - 75%
  - AUC: 0.923(A)
- **EXCELLENT**

**ACCURACY**
- 0.90 - 1: EXCELLENT
- 0.80 - 0.90: GOOD
- 0.70 - 0.80: FAIR
- 0.60 - 0.70: POOR
- 0.50 - 0.60: FAIL

Medical Fitness Center
- 20 Visitors
- 2,000,000

Chest X-Ray Exams Each Year
- 1,000,000

AI algorithm across all sites
- 1
Author:

Dr. Hassan Hagi M. Shurie (MBBS, MSc, DTM&H (UK), MRCGPint (UK))
Consultant and Head of Technical Services
Senior Lecturer Dubai Medical College
Medical Fitness & Occupational Health Department
Dubai Health Authority

Dr. Hassan Hagi Mohammed Shurie is the Consultant & Head of Technical Service Section at Dubai Health Authority Medical Fitness Centre. Dr. Shurie brings vast experience in research and infectious diseases, having held senior positions as Assistant Professor internationally and as Head of Preventive Medicine section, Primary Health Care, Department of Health and Medical Services, Government of Dubai.

Besides his current work at DHA Medical Fitness Centre, Dr. Shurie is also a Visiting Professor and teaches Infectious and Tropical Diseases. Dr. Shurie has also to his credit wealth of research publications, and is recipient of multiple awards that include Dubai Quality Award of Excellence.

Author:

Dr. Anjum M. Ahmed (MBBS, MBA, MIS, ITIL)
Global Director - Imaging Information Systems - Agfa HealthCare
www.linkedin.com/in/dranjum/

Dr. Anjum Ahmed began his clinical career as a General Physician, and over the last 19 years has been focused on change management initiatives and helping set the path to digital transformation throughout hospitals and health authorities across USA, Canada, Latin America, UK, Europe, Middle East, South Africa and Asia Pacific.

Dr. Ahmed currently leads strategic solution development initiatives at Agfa HealthCare to help healthcare organizations enable value-based care models that are centered around patients, helping healthcare organizations improve care and maximize value with their health IT investments. Dr. Ahmed’s white papers, on Value-based Care and Artificial Intelligence in medical imaging, are published and distributed widely across healthcare forums (including HIMSS).

Dr. Ahmed speaks at thought leadership events across the globe regarding the intersection of technology, machine learning and cognitive computing, its applications in healthcare, personalized care, impact on population health and early disease detection.

*The Augmented Intelligence (AI) validation in the United Arab Emirates (UAE) based on Chest X-Rays described in this article is a works in progress.