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# From Concept to Practice: An Educational Experience in the Initial Implementation of a Comprehensive Artificial Intelligence (AI) Curriculum for Medical Physicists at the 2024 and 2025 AAPM Specialty Meetings


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## INTRODUCTION

Systematic education in artificial intelligence (AI) has become increasingly important as AI tools are integrated into clinical practice in radiology, nuclear medicine and radiation therapy. To address this urgent need, the AAPM established the Ad Hoc Advisory Committee on AI Boot Camps (AHAIBC) in October 2022 to develop a structured AI curriculum and AI boot camps, while continuously updating educational contents to accommodate emerging topics.

## METHODS AND MATERIALS

A comprehensive AI curriculum was created with the assistance of generative AI, which was reviewed and refined by subject-matter experts from the AHAIBC and Working Group on Generative AI (WGGenAI).

It was organized into three volumes (I-III), 11 modules (1, 2, …), 52 sections (1.1, 1.2, …), and 245 topics (1.1.1, 1.1.2, …). Each topic included ten study questions suggested by generative AI, forming a collection of 2,450 questions (not shown in this poster).

To provide structured AI education for AAPM members, the AHAIBC organized two one-day specialty meetings, **Artificial Intelligence for Clinical Medical Physicists**, as pre-meetings to the AAPM Annual Meetings in 2024 and 2025. The meeting programs were developed from this curriculum, and the presentations are available in the AAPM Virtual Library. Each program consisted of five sessions: two morning sessions covering fundamental concepts and practical issues, one afternoon session on common applications for imaging and therapy physicists, and two synonymous breakout sessions focused on diagnostic and therapeutic applications. Strong attendance in 2024 and continued demand led to repeating the meeting in 2025 and expanding the curriculum to include generative AI topics with contributions from the WGGenAI.

## RESULTS

The curriculum begins with Volume I introducing fundamental concepts in (1) artificial intelligence, (2) machine learning, (3) deep learning, and (4) data processing. Volume II covers clinical applications in (5) diagnostic radiology, (6) nuclear medicine, and (7) radiation therapy. Volume III addresses (8) ethical, regulatory, and educational considerations, (9) information technology and big data, (10) generative AI, and (11) practical issues and case studies.

## CONTACT


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## ARTIFICIAL INTELLIGENCE FOR MEDICAL PHYSICISTS

### PART I: FUNDAMENTALS

**1. Artificial Intelligence in Healthcare**

*1.1 Basic concepts of artificial intelligence (AI), machine learning (ML) and deep learning (DL)*
1.1.1 Definition of AI, ML, and DL
1.1.2 Differences between AI, ML, and DL
1.1.3 Examples of AI, ML, and DL

*1.2 Overview of healthcare AI*
1.2.1 History and evolution of healthcare AI
1.2.2 Overview of major AI applications in healthcare
1.2.3 Strengths and advantages of using AI in healthcare
1.2.4 Limitations and challenges of healthcare AI
1.2.5 Risks associated with using AI in healthcare

*1.3 Roles of medical physicists in healthcare AI*
1.3.1 Roles in data processing and management
1.3.2 Roles in clinical implementation and integration
1.3.3 Roles in research and innovation
1.3.4 Roles in education and training

**2. Fundamentals of Machine Learning**

*2.1 History and evolution of Machine Learning*
2.1.1 Origin and early developments of ML
2.1.2 Rise of artificial neural network (ANN) and DL
2.1.3 Evolution of big data

*2.2 Machine learning paradigms*
2.2.1 Supervised Learning
2.2.2 Unsupervised Learning
2.2.3 Reinforcement Learning

*2.3 Machine learning algorithms*
2.3.1 Linear Regression
2.3.2 Logistic Regression
2.3.3 Decision Trees
2.3.4 Random Forests
2.3.5 Support Vector Machines

*2.4 Basic concepts in model development*
2.4.1 Regularization
2.4.2 Hyperparameter tuning
2.4.3 Overfitting and underfitting
2.4.4 Optimization algorithms
2.4.5 Cross-validation
2.4.6 Model evaluation metrics

**3. Deep Learning Basics**

*3.1 Basic concepts of neural networks*
3.1.1 Introduction to neural networks
3.1.2 Neurons and activation functions
3.1.3 Layers and architecture
3.1.4 Weights, bias, and loss function
3.1.5 Forward propagation and backpropagation
3.1.6 Optimization algorithms

*3.2 Convolutional Neural Networks (CNNs)*
3.2.1 Introduction to CNNs
3.2.2 Fundamentals of CNNs
3.2.3 CNN architecture
3.2.4 Training a CNN
3.2.5 Applications in medical imaging
3.2.6 U-Net architecture

*3.3 Recurrent Neural Networks (RNNs)*
3.3.1 Introduction to RNNs
3.3.2 Fundamentals of RNNs
3.3.3 Applications in medical imaging and radiation therapy

*3.4 Generative Adversarial Networks (GANs)*
3.4.1 Introduction to GANs
3.4.2 Fundamentals of GANs
3.4.3 Applications medical imaging and radiation therapy

*3.5 Autoencoders*
3.5.1 Fundamentals of Autoencoders
3.5.2 Variants of Autoencoders
3.5.3 Applications in image enhancement, radiomics, anomaly detection, and outcome prediction

*3.6 Deep reinforcement learning (DRL)*
3.6.1 Introduction to deep reinforcement learning
3.6.2 Reinforcement learning methods and the role of deep learning in reinforcement learning
3.6.3 Training deep reinforcement learning agents
3.6.4 Applications in medical imaging and radiation therapy

*3.7 Transfer learning*
3.7.1 Introduction to transfer learning
3.7.2 Techniques of transfer learning
3.7.3 Applications of transfer learning
3.7.4 Limitations and challenges of transfer learning

**4. Data Preprocessing for AI Modeling**

*4.1 Data cleaning and preprocessing*
4.1.1 Removing duplicates and inconsistencies
4.1.2 Handling outliers
4.1.3 Dealing with noise and irrelevant features
4.1.4 Handling imbalanced data
4.1.5 Data split for training, cross-validation, and testing

*4.2 Feature selection and feature engineering*
4.2.1 Univariate feature selection
4.2.2 Recursive feature elimination
4.2.3 Principal component analysis (PCA)
4.2.4 Feature extraction with deep learning

*4.3 Data processing techniques*
4.3.1 Denoising
4.3.2 Normalization
4.3.3 Data augmentation
4.3.4 Clustering

*4.4 Handling missing data*
4.4.1 Deletion methods
4.4.2 Imputation methods
4.4.3 Prediction methods
4.4.4 Handling missing data in deep learning models

### PART II: CLINICAL APPLICATIONS

**5. Diagnostic Radiology**

*5.1 Disease detection, diagnosis and classification*
5.1.1 Role and impact of ML in medical image analysis
5.1.2 ML architectures for medical image analysis
5.1.3 ML in computer-aided diagnosis (CAD)
5.1.4 ML for anomaly/disease detection
5.1.5 ML for disease classification
5.1.6 ML for image-based cancer risk assessment
5.1.7 Challenges, limitations and risks

*5.2 Image segmentation*
5.2.1 Basic principles and traditional methods
5.2.2 Overview of DL-based auto segmentation
5.2.3 DL architectures for automated image segmentation
5.2.4 Generalization of automated segmentation models
5.2.5 Model evaluation and deployment
5.2.6 Model QA and maintenance

*5.3 Image registration*
5.3.1 Basic principles and traditional
5.3.2 Overview of DL for deformable image registration
5.3.3 DL for multi-modal deformable image registration

*5.4 Image reconstruction*
5.4.1 Basic principles and traditional methods
5.4.2 Application of DL in image reconstruction
5.4.3 DL-based iterative reconstruction methods
5.4.4 DL-based noise and artifact reduction methods
5.4.5 Performance evaluation and clinical integration

*5.5 Radiomics and radiogenomics*
5.5.1 Role of radiomics in medical image analysis
5.5.2 Feature extraction and dimensionality reduction
5.5.3 Supervised vs. unsupervised learning for radiomics
5.5.4 Performance evaluation, clinical implementation
5.5.5 Model interpretation and standardization
5.5.6 Application of ML techniques to radiogenomics

*5.6 Protocol and clinical workflow optimization*
5.6.1 Design and optimization of imaging protocols
5.6.2 Automation of repetitive tasks
5.6.3 Error detection and prevention
5.6.4 Optimization of workflow and resource allocation
5.6.5 AI for clinical trials

**6. Nuclear Medicine**

*6.1 PET and SPECT*
6.1.1 Image reconstruction
6.1.2 Image enhancement, noise and artifact reduction
6.1.3 Image interpretation and analysis
6.1.4 PET/CT, SPECT/CT image fusion
6.1.5 Outcome prediction models using PET/CT

*6.2 Radiopharmaceutical therapy*
6.2.1 Fundamental principles and techniques of radiopharmaceutical therapy
6.2.2 Dose optimization and treatment planning
6.2.3 Treatment response prediction and assessment
6.2.4 Quality assurance and radiation safety

**7. Radiation Therapy (RT)**

*7.1 Simulation*
7.1.1 Organ and tumor segmentation on CT
7.1.2 Organ and tumor segmentation on MR
7.1.3 CT-MR multimodal image segmentation
7.1.4 Synthetic planning CT generation from MR

*7.2 Treatment planning*
7.2.1 Knowledge-based planning (KBP)
7.2.2 Machine learning-based dose prediction
7.2.3 Treatment plan optimization
7.2.4 Plan quality evaluation
7.2.5 Plan documentation and chart error detection

*7.3 Commissioning and quality assurance (QA)*
7.3.1 Linear accelerator commissioning
7.3.2 Periodic linear accelerator QA
7.3.3 QA of patient-specific treatment plan
7.3.4 QA of clinical AI systems

*7.4 Treatment delivery*
7.4.1 Imaging-based localization
7.4.2 Real-time tumor tracking
7.4.3 Treatment delivery error detection

*7.5 Outcome prediction*
7.5.1 Introduction to outcome prediction in RT
7.5.2 Fundamentals of ML for outcome prediction
7.5.3 Feature selection and engineering
7.5.4 Outcome prediction models
7.5.5 Model evaluation and validation
7.5.6 Model interpretability and transparency

*7.6 Adaptive radiation therapy (ART)*
7.6.1 Multimodal image registration for online ART
7.6.2 Synthetic planning CT generation from CBCT
7.6.3 Image segmentation for online ART
7.6.4 Dose prediction and optimization
7.6.5 Online treatment plan adaptation

*7.7 Brachytherapy*
7.7.1 Organ and tumor segmentation on ultrasound
7.7.2 Applicator reconstruction
7.7.3 High dose brachytherapy dose optimization

### VOLUME III: PRACTICE

**8. Ethical, Regulatory and Educational Considerations**

*8.1 Ethical considerations in big data and AI*
8.1.1 Informed consent and patient autonomy
8.1.2 Privacy and confidentiality of patient data
8.1.3 Understanding bias and fairness in ML
8.1.4 Detecting and addressing bias in ML models
8.1.5 Accountability and responsibility in decision-making

*8.2 Regulatory requirements and standards*
8.2.1 FDA regulatory landscape for AI in medical devices
8.2.2 HIPAA regulations for patient privacy and data security

*8.3 Staff training for AI implementation*
8.3.1 Importance of training for clinical staff
8.3.2 Training strategies and approaches
8.3.3 Competence evaluation of trainees
8.3.4 Evaluation of training effectiveness
8.3.5 Continuing education

**9. Information Technology and Big Data**

*9.1 Infrastructure for healthcare big data and high-performance computing (HPC)*
9.1.1 The importance of big data in healthcare
9.1.2 HIPAA-compliant cloud computing and storage
9.1.3 Other storage solutions for healthcare big data
9.1.4 HPC systems, architectures, and parallel computing

*9.2 Data processing and analytics tools*
9.2.1 Data processing tools for AI development
9.2.2 Data analytics tools in AI development
9.2.3 Data and model visualization techniques

*9.3 Programing skills for AI development*
9.3.1 Overview of software and tools for AI
9.3.2 Introduction to ML frameworks and libraries
9.3.3 Basic programming skills for AI development
9.3.4 AI tools to translate natural language to codes

*9.4 Enterprise imaging (EI)*
9.4.1 Basic concepts and principles in EI
9.4.2 Standards and platforms
9.4.3 Performance indicators
9.4.4 Integration of EI and AI

**10. Generative AI (Gen AI)**

*10.1 Fundamentals of generative AI*
10.1.1 Gen AI Evolution within the broader AI landscape
10.1.2 Core concepts, definitions and terminology
10.1.3 Differences between Gen and discriminative AI
10.1.4 Strengths and limitations

*10.2 Foundation models (FMs)*
10.2.1 Definition and basic concepts
10.2.2 Data requirements for base model trainings
10.2.3 FM training process
10.2.4 Fine-tuning of FM for downstream applications
10.2.5 Model validation and deployment

*10.3 Language and vision-based FMs*
10.3.1 Basic concepts of natural language processing
10.3.2 Evolution of large language models (LLMs)
10.3.3 LLM basic concepts and terminology
10.3.4 Transformer architecture
10.3.5 Implementation of LLMs in chatbots
10.3.6 Large vision models (LVMs)
10.3.7 Large multimodal models (LMMs)

*10.4 General applications in healthcare*
10.4.1 Data analysis, summarization, knowledge synthesis
10.4.2 Generation of clinical reports and documents
10.4.3 Clinical trial design, protocol generation, analysis and monitoring
10.4.4 Workflow automation and resource optimization
10.4.5 AI-assisted programing

*10.5 Applications in diagnostic radiology and nuclear medicine*
10.5.1 Image synthesis, processing and enhancement
10.5.2 Image reconstruction
10.5.3 Image retrieval, analysis and interpretation
10.5.4 Disease detection and characterization
10.5.5 Radiopharmaceutical dose calculations

*10.6 Applications in radiation therapy*
10.6.1 Image segmentation, registration, enhancement, and artifact reduction
10.6.2 Dose prediction and treatment planning
10.6.3 QA, error detection and incident learning
10.6.4 Clinical decision support and predictive modeling
10.6.5 Integration with radiomics

*10.7 Applications in education and training*
10.7.1 Generation of patient education materials
10.7.2 Patient engagement and communication
10.7.3 Generation of professional education materials
10.7.4 Interactive learning and exam preparation

*10.8 Challenges, risks and limitations*
10.8.1 Technical, model performance and reliability
10.8.2 Data quality, privacy and cybersecurity
10.8.3 Clinical implementation and integration
10.8.4 Ethical, regulatory and legal considerations
10.8.5 Other issues: operational, financial, educational, social and environmental

**11. Practical Issues and Case Studies**

*11.1 Integration of AI into clinical workflow*
11.1.1 Integration of AI into clinical workflow
11.1.2 Integration of AI to clinical trials
11.1.3 AI for optimization of clinical workflow
11.1.4 Medical physicists' role in AI implementation

*11.2 Uncertainty in clinical AI models*
11.2.1 Origins and types of uncertainty
11.2.2 Uncertainty's impact on treatment planning
11.2.3 Uncertainty's impact on clinical decision making
11.2.4 Safe management of uncertainty

*11.3 Model explainability, interpretability, robustness and generalization*
11.3.1 Explainable AI and model transparency
11.3.2 Interpretable architecture and feature analysis
11.3.3 Performance evaluation of interpretable models
11.3.4 Model robustness and its testing tools
11.3.5 Model generalization and transfer learning

*11.4 Challenges, risks and limitations of clinical AI implementation (non-generative AI)*
11.4.1 Limited availability of data (quality and quantity)
11.4.2 Integration with clinical workflows
11.4.3 Lack of technical expertise
11.4.4 Lack of standardization
11.4.5 Complex regulatory and ethical considerations
11.4.6 Cost and resource constraints

*11.5 Case studies on clinical AI applications*
11.5.1 Radiology report generation using generative AI
11.5.2 PET attenuation and scatter correction
11.5.3 Auto segmentation for organs and targets

## CONCLUSIONS

This comprehensive curriculum was designed as a knowledge base covering the breadth and depth of AI relevant to diagnostic radiology, nuclear medicine, radiation therapy, and medical physics. It served as the foundation for AAPM TG-455 to develop AI curricula for different audiences (e.g., graduate students and residents) and specialties (e.g., diagnostic and therapeutic medical physics).