INTRODUCTION

We present a synopsis of publications focused on machine learning (ML) or artificial intelligence (AI) applications in healthcare for the year 2019. We appreciate the work of researchers and authors who have contributed significantly to the advancement of science in this area.

METHODOLOGY

We did a PubMed search using the terms, “machine learning” or “artificial intelligence” and “2019”, restricted to English language and human subject research. This search resulted in an initial pool of 3,351 articles. Each of these were reviewed individually and exclusions (1,704) were made based on errors in the PubMed search and low scientific or clinical relevance of the individual articles. A large majority of the excluded publications focused on robotics, ontology and basic science topics.

1,647 publications were finally selected, reviewed and categorized into one or more medical specialties. 343 publications were placed into the “General” category.

REVIEW

Anesthesiology saw applications of machine learning, deep learning, artificial neural networks in predicting clinically useful outcomes like 30-day postoperative mortality, intraoperative hypoxemia, opioid overdose risk. Cardiology saw development of AI enabled ECG waveform classification, prediction of heart failure related readmission and mortality risk. Additional interest was observed in the domain of cardiac imaging. In Critical care, AI development is
focused on early identification of sepsis, hypotensive events, acute kidney injury and in AI enabled real time decision support during tele ICU care. Dermatology saw a lot of interest in the topics of AI enabled classification and diagnosis of digital images with the objective of enabling early diagnosis, especially of skin cancers. Medical Education saw some interest in introducing Natural Language Processing (NLP) to medical students. Emergency Medicine saw interest in predicting ED return visits, early identification of patients at risk for sepsis and using NLP techniques to aid triaging based on clinical notes. Endocrinology saw an interest mainly centered on identifying diabetic cohorts and risk of adverse events in diabetes using AI techniques. Classification of thyroid nodules using AI techniques on real time ultrasound images received noteworthy attention. Reported AI/ML research in Gastroenterology continues to be heavily centered on utilizing endoscopy images. Particularly noteworthy is the reporting of randomized controlled trials in this domain. NLP techniques in identifying cohorts at risk for nonalcoholic fatty liver disease were also noted.

Using AI/ML techniques to aid discovery of new drug targets, new antibiotics dominated the General literature. In terms of Dental and Head/Neck medicine, applications continue to be reported utilizing radiological and endoscopic images. Nephrology saw particular interest in prediction of early acute kidney injury and utilizing AI techniques in improving the read of electron microscopy images. Neurology's literature centered on application of AI/ML techniques in improving EEG reads as well as early diagnosis of Parkinsonism. Obstetrics/Gynecology reported interest in predicting postpartum complications including postpartum depression and NLP techniques to identify significant co-morbidities in pregnant women such as depression etc. Oncology saw interest in using AI/ML techniques in utilizing radiology, genetic data to enhance clinical care. Ophthalmology continues to be a leader in utilizing images for predicting outcomes in retinopathy, and glaucoma. Orthopedics/Rheumatology saw interest in utilizing radiological images for early recognition of osteoarthritis, automated detection of hip fractures. Intense activity continues to be reported from Pathology due to its image intensive workflows. Pediatrics literature mirrors the interest seen in adult subspecialties. Physiotherapy literature mainly centered on gait analysis. Psychiatry reported using NLP techniques for predicting patients at risk for suicide as well as using radiological images for early prediction of Alzheimer's disease. Pulmonary medicine reported intense interest in automated AI/ML enabled analysis of polysomnograms [sleep study data] and predicting risk of asthmatic exacerbations. Radiology continues to lead as expected due to its image intensive practice with clinical grade application for diagnosis and decision aids. Surgery reported interest in predicting transplant outcomes such as rejection and using NLP techniques to predict clinically meaningful outcomes.
Overall imaging, electronic health record data especially text and advanced physiological monitoring data are key drivers for innovations. Despite lot of work clinical grade applications are limited due to limited availability, and lack of synergy between healthcare institutions and industry.

**LIMITATIONS**

Search was limited to PubMed and with the restrictions mentioned in the methodology section. It is possible that some significant studies or articles might have been missed. BrainX Community’s “LEARN” (https://www.brainxai.org/learn/) section provides an extensive supplement to the review provided here. We welcome any suggestions to include publications that might have been missed. Please contact us via BrainX Community LinkedIn group, BrainX Community webpage or directly using email (pmathurmd@gmail.com).

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SPECIALITY ABSTRACTS

Anesthesiology
Dr. Michael Burns, MD, Ph.D

Machine learning (ML) and artificial intelligence (AI) applications continue to expand throughout medicine and the field of anesthesiology. In 2019 we saw applications in pain medicine, neuroanesthesia, opioid use, hospital mortality, among others. Of the 14 entries reviewed from 2019, eight were opioid or pain related. Most commonly, machine learning models were applied to solve clinical classification problems, with the most common methods including logistic regressions, neural networks, and random forests. Natural language processing (NLP) was another useful tool dedicated to ML and AI applications. Results from these original scientific studies mostly showed equivalent or improved classifications over existing clinical tools. This review highlights the rapid expansion and utility of ML and AI in the field of anesthesiology. Expansion will continue as researchers become more familiar with ML-specific tools such as Keras and ML-friendly languages such as R and Python.

Dr. Michael Burns is an anesthesiologist and clinical lecturer at the University of Michigan and clinical analytics researcher within the Multicenter Perioperative Outcomes Research Group (MPOG) (https://mpog.org/).

Dr. Burns received two Bachelor’s Degrees from the University of Michigan in 2003 (Chemical Engineering and Microbiology), Masters and PhD from the University of Wisconsin (2006 and 2009 in Chemical and Biological Engineering), and an MD from the Feinberg School of Medicine - Northwestern University in 2012. Dr. Burns completed his residency in anesthesiology from the University of Michigan in 2016 and a T32 NIH fellowship in Clinical Analytics in 2019.

Dr. Burns’ research is multifaceted comprising projects in traditional basic sciences, clinical, and computer science spaces, with a focus on creating insight and automation within medicine
through computer science technologies. This work includes clinical predictive modeling, physician decision making, scheduling, operating room workflow, billing, and quality improvement. Dr. Burns’ computer science training includes familiarity with machine learning and natural language techniques with emphasis on SQL, R, Python, Keras, and TensorFlow. Most recently Dr. Burns has published on his work on machine learning applications for automated CPT coding (PMID: 32028374).

**Critical Care**

Anirban Bhattacharyya, MD, MPH

Intensive Care units (ICUs) generate an immense amount of data compared to rest of the hospital. Early and accurate prediction of disease states, identification of new phenotypes based on clinical outcomes and understanding complex relationships between several patient factors are now possible with: (i) widespread implementation of electronic health records (EHR) and (ii) powerful computers increasing our ability to run complex machine learning algorithms that capture complex non-linear relationships across time. Prediction models for onset of different diseases like Acute Kidney Injury (AKI), Adult respiratory distress syndrome (ARDS), Pneumonia, Sepsis have been developed. Other models have focused on re-stratifying the mortality and morbidity risk once these diseases have occurred or predicting response to therapy or just improving our diagnostic accuracy by intelligently analyzing information from multiple sources. Some of these algorithms show promise with their ability to predict clinical deterioration before clinicians can detect with existing screening tools. Machine learning has allowed us to look beyond categorical variables when assessing risk. Reading through immense text data, natural language processing can help risk stratify patients or predict disease occurrence. With varied disease presentation the diagnoses can be delayed or missed by clinicians and developing models can also prove challenging. To bypass these limitations, investigators have assigned a confidence score to clinician diagnosis and defined disease phenotypes. Besides presentation, heterogeneity can also affect therapeutic responses and historically, several randomized controlled trials have demonstrated poor therapeutic efficacy. With clustering techniques, investigators have identified specific populations that will likely benefit from specific interventions and build precision algorithms specific to these phenotypes. However, as with traditional statistics, algorithms developed with machine learning techniques still suffer from bias due to inaccuracies in data collection, and lack of multi-center validation. Also, many of these algorithms, even when accurate are difficult to implement in real time due to use of very sophisticated nature. Not so surprisingly, 2019 witnessed several successful machine learning models that are built on a solid physiologic rationale with clinically relevant features that are easy to obtain. In addition, investigators are working on improving model interpretability.
and are testing models prospectively that facilitate creation of clinical decision support tools. Early implementation of these efforts has been observed in improving our mechanical ventilation strategy, in augmenting our tele-ICU practice and in triaging postsurgical patients.

Dr. Bhattacharyya is a critical care medicine trained physician, Associate Staff Physician, Critical Care Medicine, Respiratory Medicine, Cleveland Clinic, Clinical Assistant Professor of Medicine, CCLCM. He has completed a Master’s in Public Health with Biostatistics as his major. His current research efforts focus on creation of and implementation of machine learning based projects to either optimize workflow or to improve understanding of disease processes. Dr Bhattacharyya has also participated in the ESICM and SCCM datathons and was part of the winning teams.

**Cardiology**
Avirup Guha, MD, RPVI, FACC

There has been tremendous research regarding use of AI/ML based technology/methodology in the year 2019 in the field of cardiology. There were 88 manuscripts picked by our automated algorithm for use of machine learning in the field of cardiology. Of these 69 made it into the final list of articles which are included in the annual review. Like last year, the highest quality data was obtained from EKG which resulted in the highest impact manuscripts. Researchers used rhythm changes and heart rate variability to predict hypertension, myocardial infarction and left ventricular dysfunction. Additionally, researchers were able to use SVM, CNN, PCA to classify EKG into normal and arrhythmia categories including atrial fibrillation with greater than 97-99% accuracy. Ventricular arrhythmia onset was identified using a deep learning algorithm.

Cardiac MRI given its high standards of acquisition was the next great data source for ML research. Studies using CNN helped automate LGE quantification, LVEF quantification, studying myo-pericardial mechanics and aortic flow quantification. A new modality which has been used in quantification of coronary obstruction called cardiac CT fractional flow reserve (CT-FFR) was improved even further using ML techniques. Cardiovascular condition specific research using various data sources like CXR, and EMR data helped identify diagnosis, risk factors and complications among those with coronary artery disease, congestive heart failure, pulmonary hypertension and cerebrovascular disease.
Echocardiogram was another important modality used for ML research despite inter-user variability in quality. Studies using CNN focused on making sure accuracy can be achieved using 2D or 3D echo. Further, echocardiogram was utilized to diagnose early disease, and predict sudden death. CNN was used in unique ways by using heart sounds as source of data to study general cardiovascular health, diagnose congenital heart condition and predict blood pressure. There were various other scattered use cases for use of various ML algorithms discussed in the other papers.

Dr. Guha is an Assistant Professor of Medicine, Case Western Reserve University School of Medicine, Cleveland, OH and a consultant cardiologist in the Harrington Heart and Vascular Institute

Emergency Medicine
John S Lee, MD

Emergency departments are awash in physical chaos. This chaos is very much reflected in the data that the typical emergency physician must ingest and parse. Machine learning techniques provide hope that this chaos can be tamed and clinically useful information can obtained.

Rapid triage in the emergency department is a key competency. Unfortunately, this process has been very dependent on mistake prone human processes that can become overwhelmed by the emergency department's sensory overload. 2 studies used triage data to predict whether patients would eventually need critical care. These studies yielded critical care predictions using machine learning techniques with AUROCs of 0.78-0.87. One of the studies also predicted overall hospitalization with AUCs of 0.73 to 0.80.

An intriguing study used various NLP techniques to analyze free text nursing triage notes to predict disposition. The composition of the limited triage nurses' notes yielded predictions of a
patient's final disposition with AUROCs of 0.687-0.785. This reinforced the untapped potential of unstructured notes.

Beyond identifying and acutely treating patients who need immediate acute medical care, the emergency department can serve as a significant public health resource, particularly as a screening facility to detect future, longitudinal health problems such as falls. One center studied 3 different algorithmic approaches were used to predict falls within 6 months after and ED discharge. The best performing model was a random forest model which achieved an AUROC of 0.78. Based on these results, the authors postulated that they would have to send 12 referrals to a fall clinic to prevent 1 eventual fall.

The bane of the emergency physician is the patient who goes home but then returns soon afterward. These decisions are frequently made heuristically and with limited data. Leveraging data to aid in the decision to send a patient home could help emergency physicians avoid the dreaded conversation with a colleague, "You know that patient you sent home yesterday..." One center studied a tool to predict return to the ED within 120 hours after discharge. They used 2 different models which yielded accuracies of 81-91.3%. At another site, social determinant data was studied to see if it could predict returns to the emergency department both combined with other clinical data and on its own. Social determinant data yielded AUROC performance of only 0.61. Combining social determinant with EHR and HIE data yielded AUC performance of 0.732.

And of course, no review of predictive models in the emergency department would be complete without the obligatory sepsis predictions. Investigators developed a Risk of Sepsis (RoS) score and compared it to a more traditional Sequential Organ Failure Assessment (SOFA). RoS was significantly more sensitive and precise. A Singapore facility compared machine learning assessment of ED patients to predict sepsis. They too were able to generate a model that outperformed more traditional risk stratification tools such as the Quick Sequential Organ Failure Assessment (qSOFA), National Early Warning Score (NEWS), Modified Early Warning Score (MEWS), and Singapore ED Sepsis (SEDS).

Dr. John Lee is an emergency physician and chief medical information officer at Edward-Elmhurst healthcare. He completed his residency training at Cook County Hospital. He has been practicing emergency medicine for more than 20 years and has been actively involved in clinical informatics for 14 years. He is passionate about the use of data and information technology to solve the many ills of our health care system.
Gastroenterology
Rajasekhar Mummadi MD, MS

Published work in the field of Artificial Intelligence (AI) and Machine Learning (ML) in Gastroenterology and Hepatology in 2019 can be broadly divided into two categories:

1. Convoluted Neural Networks (CNN) to enhance the detection of gastrointestinal lesions and for real-time histology during endoscopy. Colonoscopy done for Colorectal Cancer (CRC) screening is one of the most common gastrointestinal (GI) endoscopy procedures performed across the world. It has been established that the protective effect of a colonoscopy arises from the detection of precancerous polyps. The quality of the procedure and the subsequent decrease in mortality is directly proportional to the Adenoma Detection Rate (ADR) and Polyp Detection Rate (PDR). It is not surprising that a significant amount of studies in 2019 focus on the application of Convoluted Neural Networks (CNN) to enhance real-time detection of polyps during colonoscopy and precancerous lesions during upper GI endoscopy. Wireless Capsule Endoscopy (WCE) saw a significant amount of progress in the application of machine learning to improve detection. WCE is a high definition of video footage of the small bowel acquired by an ingested camera that runs for around 4-6 hours. Operator distractibility and fatigue lead to missed lesions. An earlier version of machine learning used a color filter to pick up bleeding lesions. Given the baseline of achievements, this reported progress in algorithms is expected to enhance the detection of lesions. It is interesting to note that Gastroenterology leads the way in Randomized Controlled Trials (RCTs) of AI applications in medicine to date, and 3 out of 4 examine the impact of AI on polyp detection in colonoscopy.

2. Enhance Prognosis and Diagnosis of GI diseases: Multiple studies have been done in using machine learning techniques to predict outcomes of chronic gastrointestinal diseases such as Crohn’s disease, Non-Alcoholic Fatty Liver Disease (NAFLD), and Hepatitis C. In this segment, ML techniques are expected to outperform traditional regression models by incorporating unstructured data with techniques such as Natural Language Processing. VanVleck, Chan, and colleagues used Natural Language Processing (NLP) technology to identify patients with NAFLD. Dong et al. used a
Machine Learning (ML) model to predict the risk of surgery in Chinese patients with Crohn’s disease. Zhao and Liu used an ML model based on logistic regression and Support Vector Machine (SVM) to explore the relationship between traditional risk factors (age, weight) and the evolving discipline of the fecal microbiome in predicting the risk of colorectal cancer.

Strengths of the published literature include the reporting of 3 randomized controlled trials. Limitations include a lack of description of integration into daily clinical workflows.

Dr. Mummadi is a board-certified gastroenterologist and the Chief Quality and Population Health Officer for Northwest Permanente, the physician group of Kaiser Northwest. He is passionate about the integration of big data analytics in healthcare delivery to improve care delivery. He leads the organizational governance group charged with evaluating evolving ML technologies in health care.

General Sandeep Reddy MBBS PhD MSc FAcadmTM CHIA

The growing utilization of Machine Learning (ML) in various aspects of healthcare research and delivery has been showcased in a staggering number of peer-reviewed articles in recent years. The studies outlined in these articles demonstrate the versatility of ML in addressing various kinds of medical complications. Not just problems, ML methods are being used to pave the way for innovative medical interventions that would have been previously impractical to implement. The collection of articles, all published in 2019, listed in this section while having an emphasis on personalized medicine and drug discovery, also present insights about the use of classical and novel ML methods in healthcare. Also, there are reviews in this section as to how various
medical domains are utilizing ML methods to deliver better medical care and improved patient outcomes.

Drug discovery is a resource-intensive process. Articles listed in this section showcase how ML can make this process more efficient including how ML can help with drug repositioning (Zong, N., et al. 2019), support text mining to enable drug discovery (Zheng, S., et al. 2019), and predict drug target interaction (Yan, X. Y., et al. 2019) amongst other applications. Increasingly ML methods are driving adoption and delivery of personalized medicine, which involves the provision of medical treatment tailored to individuals. Zhang, S., et al.(2019) discuss how ML is supporting personalized medicine components like disease characteristic identification, therapeutic effect prediction and tailored drug development. Also, Yao, J., et al. (2019) discuss how the use of ML methods can computationally identify various therapeutic hypotheses by calculating clinically useful drug targets.

Amongst the ML techniques showcased in the over 300 articles in the section, Natural Language Processing (NLP) has a certain prominence. Zeng, Z., et al. (2019) discuss how it can be used for Electronic Health Record phenotyping which in turn can assist with diagnosis and treatment. Zhu, V. J., et al. (2019) also discuss how NLP pipelines such as data from EHR and medical reports can reduce social isolation. Further, NLP can foster in-silico drug discovery through text mining of biomedical science literature as per Zheng, S., et al. (2019).

Other methods discussed in the articles include reinforcement learning, which is exemplified in the design of a closed-loop control of drug dosing administration (Yazdjerdi, P., et al. 2019), an unsupervised deep learning-based feature learning to analyse heterogenous patient health data (Zhou, C., et al. 2019), support vector machine algorithm to predict blood pressure from physiological index data (Zhang, B., et al. 2019), and a fuzzy multi-objective linear model to address medical service organization selection issues and uncertain information (Liao, S., et al. 2019). These are just some of the hundreds of ML models profiled in the articles indicating not
just the diversity of ML methods but also a rapidly evolving field where novel ML techniques emerge each year.

This section also presents commentaries about the role of ML and Artificial Intelligence (AI) in general in healthcare planning, administration and delivery and what it means for clinicians and patients. These articles complement the translational medicine papers, as they present something for decision makers to ponder as it is increasingly becoming evident that ML is no fad or fading technology and has become real and useful to healthcare delivery.

Associate Professor Sandeep Reddy MBBS PhD MSc FAcadmTM CHIA.
Sandeep is an Artificial Intelligence (AI) in Healthcare researcher based at the Deakin School of Medicine besides functions as a certified health informatician, and a World Health Organization recognized digital health expert. He has a medical and healthcare management background and has completed machine learning/health informatics training from various sources. He is currently engaged in research about the safety, quality and explainability of the application of AI in healthcare delivery in addition to developing AI models to treat and manage chronic diseases. Also, he has authored several articles and books about the use of AI in Medicine. Further, he has set up local and international forums to promote the use of AI in Healthcare in addition to sitting on various international committees focusing on AI in Healthcare.

Oncology
Aziz Nazha, MD

Artificial intelligence (AI) and machine learning (ML) had a significant impact on our lives and certainly, this impact started to be seen in medicine. Oncology as a subspecialty can have a great benefit from the application of this technology. Last year, tremendous work has been done to use machine learning and deep learning to improve the diagnostic accuracy, prognosis and treatment
selection for cancer patients. These efforts included the identification of prostate cancer and other solid tumor cancers in pathology slides using computer vision, to profiling solid tumor cancers using electronic health records. Other attempts included the development of personalized prediction model to predict prognosis of cancer patients that is specific for a given patient. Further, interesting efforts were made to integrate multi-modality approaches using imaging, clinical data and genomic data to predict response to chemotherapy and immunotherapy along with several efforts to develop or design new targeted therapies using deep learning. All these efforts highlight the importance of AI technologies in advancing cancer research and improve patient outcomes.

Dr. Nazha is a Hematologist & Oncologist who practices at the Cleveland Clinic Foundation, OH. His interests are in application of AI & ML techniques to improve the care of his patients. He leads the Cleveland Clinic's Center for Clinical Artificial Intelligence which is coordinating efforts between physicians, researchers, computer scientists and statisticians for exploring AI/ML opportunities in advancing clinical care. He led the creation of a new model that incorporates individual patient genomic and clinical data to better predict overall survival and the risk of leukemia in patients with myelodysplastic syndrome.

**Psychiatry and Behavioral Sciences**
Jungwon Cha, PhD, Amit Anand, MD

In 2019, Artificial Intelligence (AI) research in mental health has focused on machine learning and Natural Language Processing (NLP). Machine learning-based predictive analysis algorithms have used supervised machine learning methods such as support vector machine, decision tree, random forest, and logistic regression as well as unsupervised machine learning methods like k-means clustering and hierarchical clustering. It should be noted that AI research is rapidly moving more towards deep learning approaches using Convolutional Neural Network (CNN) but only a few mental health studies have reported results using these methods.

AI research in mental health has focused on brain connectivity research using data from structural and functional Magnetic Resonance Imaging (MRI) as well as Electroencephalography (EEG) data to predict psychiatric disorders diagnosis, suicidal behavior as well as several types of addictions. Electronic Health Records (EHR) data has also been used to predict postpartum depression and identify suicidal behavior. Several different machine learning methods using data from structural MRI, resting-state functional MRI, Diffusion Tensor Imaging (DTI), and
brain morphometry have attempted to classify schizophrenia subjects from other psychiatric disorders as well as from healthy subjects. Machine learning method studies also reported using classification between bipolar from unipolar depression using brain imaging and EEG data. A number of publications related to NLP interpretation of EHR and MRI data have also been reported to identify subjects at risk for suicide. Machine learning methods applied to the brain connectome were also reported for classification of subjects at risk for addictions and to predict relapse of addictive behavior.

LIMITATIONS

Even though considerable progress has been made in the application of AI methods in mental health, many of the studies were limited by a small size which affects the predictive power of the model that was used. Furthermore, differences in the type of methods and models used in different studies make it difficult to compare results across studies.

Jungwon Cha received the B.S. and M.S. degrees in Physics from the Yonsei University, South Korea, in 2006 and 2008, respectively, and the Ph.D. degree in electrical and computer engineering from University of Louisville, USA, in 2018.

In 2018, he started post-doctoral research fellow in the center for behavioral health in the Cleveland Clinic. His current research interests include resting state fMRI, DTI, machine learning, classification, and mood disorders.

Dr. Amit Anand is Professor of Medicine at the Cleveland Clinic Lerner College of Medicine. He holds the position of Vice-chair for research for Center for Behavioral Health and directs the Mood and Emotional Disorders Across the Life Span (MEDALS) program at the Cleveland Clinic. Dr. Anand completed his initial medical and psychiatric training from the All India Institute of Medical Sciences and the Royal Australian and New Zealand College of Psychiatrists. In 1992 he came to Yale University School of Medicine where he completed a Clinical Neuroscience fellowship. Subsequently he joined the Yale University School of Medicine faculty as assistant professor and directed the bipolar disorders clinical and research program there. While at Yale, Dr. Anand completed several innovative brain imaging and pharmacological studies on the biological basis of mood disorders. In 2001 he was offered a tenured professorship appointment at Indiana University School of Medicine and he established the mood disorders clinical and research program there. At Indiana University School of Medicine he conducted pioneering studies of abnormalities in
brain connectivity in mood disorders and was funded by the National Institutes of Health. Dr. Anand moved to Cleveland Clinic in 2012 where he has established a diverse clinical research program in areas of personalized medicine, brain imaging, and novel treatment trials for mood and other neuropsychiatric disorders. Dr. Anand has obtained several NIH grants as well as private foundation grants and has also conducted numerous clinical trials. He has more than a hundred publications in the areas of psychopharmacology and biomarkers of mood disorders and is nationally and internationally recognized in these areas.

**Pulmonary Medicine**
Srinivas R Mummadi, MD, MBI

Asthma is a strong area of interest. The holy grail of asthma has been to identify patients responsive to a unique class of medicines (ex: inhaled corticosteroids). A study used multiple kernel k-means clustering to identify clusters of patients (based on their responsiveness to inhaled corticosteroids) from the Severe Asthma Research Program cohort (n=349 patients). They could identify 12 variables that could predict the cluster of severe asthmatics. These findings have the potential to aid real time decision support during outpatient evaluations and aid precision medicine efforts. Limitations of this study include the absence of validation efforts and lack of integration with the electronic health record workflows.

2019 has seen a strong interest in using convolutional neural networks to improve efficiency of interpreting sleep studies (n= 6 studies). Fundamental steps of interpreting sleep studies include analyzing vast amounts of visual data for each patient and therefore this development will accelerate efforts in promoting efficiency in the turnaround time of sleep study results. Turnaround time of sleep study results is a well-known indicator of patient satisfaction. Limitations of published literature in this domain include relatively sample size and only one study describing validation efforts.

An area of interest that has seen three efforts is using deep learning techniques for classifying auscultatory lung sounds and breathing patterns. One model could classify with a high degree of accuracy 522 lung auscultation samples from 50 patients. One study used a non-contact Doppler radar to understand patterns in breathing sounds to classify the observations into 6 well known breathing patterns which are suggestive for unique diseases. Potential applications of this line of work include improving the performance of current electronic stethoscopes, teaching, quicker diagnosis during tele-health consultations and risk stratification during first response evaluations.

A particularly interesting effort to predict high cost Chronic Obstructive Pulmonary Disease (COPD) patients was described from China. The authors analyzed data of 186,188 patients with COPD using a smooth Bayesian network to predict future high cost COPD patients. The AUC was 0.80 and outperformed existing machine learning models. It also unearthed interesting patterns such as a “geographic hotbed of high cost COPD patients” and primary hospital care
being reflective of an increased risk of transitioning to a high cost COPD patient. These are very important efforts as they seek to solve wicked problems on a population health scale.

As expected, efforts at improving chest image interpretation continue to be reported. Inherent limitations of such efforts continue to be a relatively small training sample and lack of descriptions about integrating these tools in the actual workflow of chest radiologists. A study from an academic medical center described a NLP project to understand the prevalence of ground glass opacity (a pulmonary nodule with a high risk of low grade cancer) in their organization. Such work has applications in population health, quality improvement and case detection.

Future efforts should incorporate validation descriptions as well as offer practical examples of workflow integration.

Dr Mummadi is a Staff Physician at the Respiratory Institute and Medical Director of Clinical Informatics, Cleveland Clinic Foundation, OH. He has formal training background and is board certified in Internal Medicine, Pulmonary and Critical Care Medicine, Clinical Informatics and Medical Quality. He has interests in using informatics to improve health care quality and analyzing large outcomes databases. Clinical interests include obstructive lung disease and pleural disease.

Radiology
Ty Vachon, MD

The barrier for small hospitals and systems to adopt radiology AI algorithms, clinical or otherwise, remains high. Large, research based, or at least research minded, institutions can work on projects as their appetite dictates. The distribution of the 2019 research continues to reflect this trend. Most of the research, while laser focused on the problem they solve, is not ready to answer usable clinical questions, solve real workflow issues or improve specific disease outcomes.

The nature of AI lends research to initially focus on classification, segmentation and diagnosis however a reasonable number are looking further at treatment response and predictive outcomes, which is refreshing. Understandably, we are still in the relatively early stages of AI as applied to medical imaging and the disease or injury must be first identified prior to re-identified after treatment or evaluated for predictive measures. Even at our early stage, I am encouraged by the
authors who have worked to demonstrate treatment response and prognosis prediction in brain, vascular, cardiac, liver, prostate, breast and chest.

Choosing a very specific disease entity and associated feedback loop, or predictive therapeutic guidance, can realize direct clinical application. This can improve the time to FDA approval and ultimately utilized on my reading list, and as a practicing radiologist, that is my preferred outcome.

The 5 most researched anatomic regions of 2019 are of no surprise: brain, lung/chest, breast, heart, liver. The next group were head/neck including thyroid, spine, bones and joints and female pelvis. About two-thirds of the studies discussed modality with MRI and CT accounting for nearly all of them at about 100 studies each. Sonography, mammography and PET accounted for the majority of the remaining 60 studies. A handful of studies looked at plain film and fluoroscopy.

For now, the predictable volumetric rendering of CT and MRI with stacked images and known interval seems to be most suitable for algorithm development. Given the wide user variability in sonography it is understandably more difficult to acquire larger training sets, with the exception being breast lesion evaluation. Possibly the strict BIRADS method of reporting has been helpful in the breast ultrasound image acquisition and subsequent utility in algorithm development.

From a quality standpoint it was encouraging to see about one quarter of the studies in 2019 at least partially addressed systems and quality. There are many areas in radiology, with direct and indirect interaction with larger health system, which could be streamlined with algorithm applications to include billing, scheduling, exam protocols, radiation dose, appropriateness and patient education. It would be nice to see more research in these areas as well.

Radiologists are ready to see prudent deployment of well implemented, safe, explainable algorithms, and I am looking forward to the progression of the 2019 research to continue to work toward this goal.

Dr. Vachon has been recognized by the American Medical Association's Physician Innovation Network as an innovator and leader and he has served as an expert panelist on artificial intelligence in medicine. As an AI thought leader, he was interviewed by the Radiological Society of North America at the recent 2019 RSNA trade show. His most recent print publication “A Radiologist’s Introduction to AI and Machine Learning” has been delivered to over 1500 practicing radiologists worldwide with the goal of educating his peers and advancing our field, one person at a time.


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