



Al and Deep Medicine

@erictopol





Medical Diagnostic Errors in the United States

>12 million per year

"Most people will experience at least 1 diagnostic error in their lifetime."

If the correct diagnosis was thought of in the first 5 minutes, accuracy = 98%, if not 25%

At autopsy, doctors who were "completely certain" of the cause of death were wrong 40% of the time





A new era of health care is coming. **PRECISION MEDICINE** will monitor our health moment to moment, predict our risk of cancer

predict our risk of cancer, heart disease, and other ailments and devise treatments tailored to each of us.

EVERY BODY SUNQUE













Science 15 FEBRUARY 2019

Skilful precipitation nowcasting using deep generative models of radar



29 September 2021

nature

DeepMind's AI predicts almost exactly when and where it's going to rain

The firm worked with UK weather forecasters to create a model that was better at making short term predictions than existing systems.



Target

DGMR

UNet



PySTEPS





Deep Convolutional Neural Network–based Software Improves Radiologist Detection of Malignant Lung Nodules on Chest Radiographs

Radiology 11 November 2019



Deep Neural Networks Improve Radiologists' Performance in Breast Cancer Screening

> 1 million images, AUC0.895 w/ 14 radiologists

"We also show that a hybrid model, averaging the probability of malignancy predicted by a radiologist with a prediction of our neural network, is more accurate than either of the two separately"











17 October 2019

Toward robust mammography-based models for breast cancer risk



~100,000 patients at 3 health systems, predict risk at multiple time points, GAN



Best prior model high 5-yr risk 23%; Mirai 42%

27 January 2021



Schematic description of Mirai

Gender



Actual: Female Predicted: Female

What the Machine Sees in the Retina

Kidney Disease



A deep learning algorithm to detect chronic kidney disease from retinal photographs in community-based populations

Lancet Digital Health May 12, 2020

Diabetes and Blood Pressure Control





DBP

Actual: 78.5 mmHg

Predicted: 86.6 mmHg

March 2018

Actual: non-diabetic Predicted: 6.7% Actual: 148.5 mmHg Predicted: 148.0 mmHg

Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning

biomedical engineering

Alzheimer's Disease



A system based on AI will scan the retina for signs of Alzheimer's



Heart Calcium Score



Lancet Digit Health Apr 2021







Predicting conversion to wet age-related macular degeneration using deep learning May 2020

Liver and Gall Bladder Disease



Lancet Digit Health Feb 2021

What the Machine Sees in the ECG

Age and Sex



Sex = female; Age = 66 years CNNsex = female; CNNage = 66.2 years Sex = female; Age = 85 years CNNsex = female; CNNage = 69.7 years

Circulation: Arrhythmia and Electrophysiology

27 August 2019

Cardiac



Screening for cardiac contractile dysfunction using an artificial intelligence-enabled electrocardiogram

medicine



An Artificial Intelligence-Enabled ECG Algorithm to Identify Patients with Left Ventricular Systolic Dysfunction Presenting to the Emergency Department with Dyspnea

Anemia



A deep learning algorithm to detect anaemia with ECGs: a retrospective, multicentre study Lancet Digital Health 2020; 2: e358–67

Circulation: Cardiovascular Quality and Outcomes

September 2019

Geoffrey H. Tison, MD, MPH*

Francesca N. Delling, MD

Rahul C. Deo, MD, PhD

Jeffrey Zhang, BA*

MDH

Difficult Diagnoses

Automated and Interpretable Patient ECG Profiles for Disease Detection, Tracking, and Discovery





Artificial intelligence-enabled electrocardiograms for identification of patients with low ejection fraction: a pragmatic, randomized clinical trial

Routine ECG in patients without prior heart failure

New diagnosis of low EF (<50%) within 90 days

Overall, 2.1% vs 1.6% (OR 1.31), P=0.007

Improved diagnosis rate 19.5% vs 14.5%. (OR 1.43), P=0.001 [in 6% with + AI-ECG]

Echo use increase: 49.6% vs 38.1%

medicine May 2021



What the Machine Sees in on a Slide



mutations, tumor composition and prognosis July 2020

Driver Mutations

Prognosis

Nature AI-based pathology predicts origins for cancers of unknown primary



(28.2 TB)

TOAD-tumor origin assessment via deep learning

5 May 2021

Deep learning-based artificial intelligence model to assist thyroid nodule diagnosis and management: a multicentre diagnostic study





Lancet Digit Health 2021; 3: e250–59

Using deep learning to identify the recurrent laryngeal nerve during thyroidectomy





scientific reports 12 July 2021









How AI Will Transform Health Professionals

Clinician Category	Data Interpretation
Radiologists	Scans
Pathologists	Slides
Dermatologists	Skin Lesions
Ophthalmologists	Eye Exams
Cardiologists	ECG, Echo
Psychiatrists	Psych Status
Gastroenterologists	Scopes
Oncologists	Omics, Rx
Geneticists	Face, BAM file
Palliative Care	Predictions
All Doctors	Delete Keyboards
Nurses	Vital signs
Pharmacists	Drugs







AI Across the Healthspan





Rapid AI Medicine for Critically III Infants



Genomic Medicine

Every minute without a diagnosis counts

The fastest possible diagnosis in 13.5 hours for these babies, using AI tools to optimize for speed and performance



Clinical Natural Language Processing (CNLP)

CliniThink or CLAMP, transforms unstructured EHR data into a structured list of Human Phenotype Ontology Terms

CliniThink has been **iteratively trained on Rady Children's electronic health records** for optimum performance in extraction of terms relevant to rare genetic diseases



Automated Interpretation Reduces Analytic Time

GEM (Fabric Genomics) and MOON (InVitae) GEM accurately made Prioritizes and ranks variants this diagnosis of isolated sulfite oxidase **deficiency** due to a mutation in the SUOX gene #469281 SUOX Condition: SULFITE OXIDASE DEFICIENCY, ISOLATED -OMIM ENST00000394109 Autosomal Recessive HPO TERMS CASE INFO USP7 Condition: CHROMOSOME 16P13.2 DELETION SYNDROME -OMIM Encephalopathy Hydrocephalus Seizure ENST00000344836 Autosomal Dominant Respiratory failure Death in infancy Feeding difficulties in infancy Lactic acidosis LYST Condition: CHEDIAK-HIGASHI SYNDROME -OMIM 0.8 ENST0000389793 7 HPO terms Autosomal Recessive

Rapid, Precision Management for Rare Genetic Conditions

<u>Genome-To-Treatment</u> (GTRx)

an automated system for immediate, 24-hour management of newly diagnosed genetic conditions

Al was used to pull references for a list of 358 severe, treatable genetic conditions and extract relevant interventions

Available in a web resource for frontline clinicians



Rapid Sequencing-Based Diagnosis of Thiamine Metabolism Dysfunction Syndrome



3 June 2021

The NEW ENGLAND JOURNAL of MEDICINE

Α

Using AI to Sharpen Image Quality, Less Acquisition Time, Less Contrast MRI and PET



AUTOMATION

Your robot surgeon will see you now

Autonomous systems are beginning to equal human specialists at precision surgical tasks. This could lead to a shift in what it means to be a surgeon.

DEEP MEDICINE

Man v machine

Predicted year machines will match human performance



Sources: Oxford University; Yale University

nature biomedical engineering

Explainable AI predicts blood-oxygen levels during anaesthesia

nature biomedical engineering

а

https://doi.org/10.1038/s41551-018-0304-0

Explainable machine-learning predictions for the prevention of hypoxaemia during surgery

Scott M. Lundberg ¹, Bala Nair^{2,3,4}, Monica S. Vavilala^{2,3,4}, Mayumi Horibe⁵, Michael J. Eisses^{2,6}, Trevor Adams^{2,6}, David E. Liston^{2,6}, Daniel King-Wai Low^{2,6}, Shu-Fang Newman^{2,3}, Jerry Kim^{2,6} and Su-InLee^{1*}



Tool Detection and Operative Skill Assessment in Surgical Videos Using Region-Based Convolutional Neural Networks

Automatically detect surgical instruments





Input video of surgical procedure Output video with surgical

instruments detected



Extract metrics using tool detection results to assess operative skill



	Video 1	Video 2	Video 3	Video 4
Depth Perception	2.67	4.67	2.33	3.67
Bimanual Dexterity	3.00	4.67	2.00	3.33
Efficiency	2.00	4.67	2.33	3.00
Tissue Handling	2.33	4.67	2.67	3.33
Total	10.00	18.67	9.33	13.33



Total time each instrument is used

Jin et al, arXiv, 22 July 2018

nature First-in-human study of the safety and viability of intraocular robotic surgery



The surgeon's view of a live intraoperative feed from optical coherence tomography of the eye.

The peeling of retinal membranes can be safely conducted with robotic assistance.

Edwards, Sept 2018
medicine

17,803 admissions | 5 ICUs 79,073 admissions | 128 hospitals Model for individualized patient AI: Better use of (less) IV fluids, (higher dose) vasopressors, medications

"AI Clinician is on average reliably higher than human clinicians"

Chosen policy

AI

100

50

0

-50

-100

Estimated policy value

+

Clinicians

The Artificial Intelligence Clinician learns optimal treatment strategies for sepsis in intensive care











How AI Will Transform Health Professionals

Clinician Category	Data Interpretation
Radiologists	Scans
Pathologists	Slides
Dermatologists	Skin Lesions
Ophthalmologists	Eye Exams
Cardiologists	ECG, Echo
Psychiatrists	Psych Status
Gastroenterologists	Scopes
Oncologists	Omics, Rx
Geneticists	Face, BAM file
Palliative Care	Predictions
All Doctors	Delete Keyboards
Nurses	Vital signs
Pharmacists	Drugs







Illuminating the dark spaces of healthcare with ambient intelligence

	Camera	Depth sensor	Thermal sensor	Radio sensor	Acoustic sensor
Sensory information	RGB, colour, video	Lidar	Infrared	Radar, Wi-Fi	Microphone
Function	Measures colour (visible light)	Measures distance to objects	Measures surface temperature	Estimates distance and velocity	Measures air pressure waves (sound)
Sampling rate	30 Hz (1,920 × 1,080)	30 Hz (1,280 × 720)	10 Hz (640 × 480)	800 Hz	44.1 kHz
Bit depth	24 bits	16 bits	16 bits	32 bits	16 bits
Uses	Object recognition, person detection	3D object detection, robotic navigation	Night vision, equipment safety	Motion detection, object detection	Speech recognition, event detection
Data visualization					







Illuminating the dark spaces of healthcare with ambient intelligence

			IC	ICUs		ng rooms
Challenge	Sub-challenge	Technical approaches	Patient mobility	Hand hygiene	Skills	Surgical count
Behaviour recognition in complex scenes	Complex environments	Visual tracking, matrix completion	Х	Х	Х	x
	Locating multiple humans	Pedestrian detection, human pose estimation	Х	-	_	-
	Recognizing human behaviours	Scene graphs, activity recognition	Х	Х	-	x
Learning with big data and rare events	Big data	Distributed learning, optimizers	Х	Х	Х	x
	Real-time detections	Two-stage models, model compression	-	Х	х	x
	Rare events	Calibration, loss weighting	х	-	-	х
	Generalization to new environments	Transfer learning, few-shot learning	Х	Х	x	X



Prospective Trials In A Clinical Environment Assessing Performance of AI Deep Neural Networks

Specialty	Input	Citation
Ophthalmology	Diabetic retinopathy	Abramoff, NPJ Digital Medicine 2018
	Diabetic retinopathy	Gulshan, JAMA Ophthalmology 2019
	Diabetic retinopathy	Kanagasingam, JAMA Open, 2018
	Congenital cataracts	Long, Nature Biomed Engr, 2017
Pathology	Breast cancer metastases	Steiner, Am J Surgical Path, 2018
Radiology	Brain CT hemorrhage	Lee, Nature Biomed Engr, 2019
Gastroenterology	Colonic polyp detection	Mori, Annals Int Medicine, 2018
	Nasopharyngeal cancer	Li, Cancer Communications, 2018
Dermatology	Skin cancer detection	Dascalu, EBioMedicine, 2019
	Skin melanoma	Phillips, JAMA Open, 2019
Neurosurgery	Intraoperative Brain imaging	Hollon, Nature Medicine, 2020

Randomized Trials of AI Deep Neural Networks in Medicine

Procedure	Detection	Design	N Patients	N Sites	Place	Citation
Colonoscopy	Adenomas	Double-blind, sham control	1046	1	China	Wang P, Lancet Gastro Hep 2020
Colonoscopy	Adenomas	Unmasked	704	1	China	Gong D, Lancet Gastro Hep 2020
Colonoscopy	Adenomas	Unmasked	659	1	China	Su et al, Gastro Endoscopy 2020
Esophagogastro- duodenscopy	Blind spots	Unmasked	324	1	China	Wu L, Gut 2019
Colonoscopy	Adenomas	Unmasked	1058	1	China	Wang P, Gut 2019
Slit-lamp Photography	Childhood Cataracts	Unmasked	350	5	China	Lin H, E Clinical Medicine 2019
Intraoperative	Low BP	Unmasked	68	1	Netherlands	Wijnberge M, JAMA, 2020
Medical dispatch calls	Cardiac arrest	Masked	5242	NA	Denmark	Bloomberg, JAMA Network, 2021
ECG	Low EF	Unmasked	22,641	45	USA	Yao et al, Nature Medicine 2021

nature.com/nm **September 2020 Vol. 26 No. 9**

Guidelines for AI in clinical trials Physical activity and health outcomes AI-guided insulin dosing

Welcoming new guidelines for AI clinical research

With only a limited number of clinical trials of artificial intelligence in medicine thus far, the first guidelines for protocols and reporting arrive at an opportune time. Better protocol design, along with consistent and complete data presentation, will greatly facilitate interpretation and validation of these trials, and will help the field to move forward.

Eric J. Topol

CONSENSUS STATEMENT https://doi.org/10.1038/s41591-020-1034-x

medicine

Check for updates

OPEN

Reporting guidelines for clinical trial reports for interventions involving artificial intelligence: the CONSORT-AI extension

Reporting guidelines for clinical trial reports for interventions involving artificial intelligence: the CONSORT-AI extension Guidelines for clinical trial protocols for interventions involving artificial intelligence: the SPIRIT-AI extension





The smart devices

FDA approvals of artificially intelligent medical devices, by type



Date of Final Decision	•	Submission Number	•	Device	Company	•	Panel (Lead) 🔶	Primary Product Code	•
01/02/2020		<u>K183089</u>		Air Next	NuvoAir AB		Anesthesiology	BZG	
05/05/2017		<u>K163665</u>		MATRx Plus	Zephyr Sleep Technologies		Anesthesiology	MNR	
11/05/2015		<u>K150102</u>		SnoreSounds	Appian Medical Inc.		Anesthesiology	MNR	
03/11/1997		<u>K955841</u>		Compumedics Sleep Monitoring System	Computmedics Sleep Pty. Ltd.	•	Anesthesiology	MNR	

"Machines will not replace physicians, but physicians using AI will soon replace those not using it."

Antonio Di leva







People have the AI power

mature machine intelligence

PERSPECTIVE https://doi.org/10.1038/s42256-021-00331-0

Direct-to-consumer medical machine learning and artificial intelligence applications





Google launches AI health tool for skin conditions

Breakthrough development will assist users in self-diagnosing issues ranging from acne to melanoma





Google's new AI tool Derm Assist © Google

skin area

JAMA Network Open...

Original Investigation | Dermatology

Development and Assessment of an Artificial Intelligence-Based Tool for Skin Condition Diagnosis by Primary Care Physicians and Nurse Practitioners in Teledermatology Practices

Ayush Jain, MS; David Way, ME; Vishakha Gupta, MS; Yi Gao, PhD; Guilherme de Oliveira Marinho, BS; Jay Hartford, MS; Rory Sayres, PhD; Kimberly Kanada, MD; Clara Eng, PhD; Kunal Nagpal, MS; Karen B. DeSalvo, MD, MPH, MSC; Greg S. Corrado, PhD; Lily Peng, MD, PhD; Dale R. Webster, PhD; R. Carter Dunn, MS, MBA; David Coz, MS: Susan J, Huang, MD: Yun Liu, PhD: Peggy Bui, MD, MBA: Yuan Liu, PhD



× Submit photos and symptoms

Step 1 of 10

Take a close-up photo

Make your photo clear and focus it directly on the affected skin area

Q Photo tips







Computer vision app turning your smartphone into a medical device

Healthy.io Scanwell **NI** INU testcard

First FDA Cleared Deep Learning Algorithms for Consumers





2017







 TABLE 12.1: My list of twenty-four reasons why you need to own your

 health and medical data.

lt's your body.

You paid for it.

It is worth more than any other type of data.

It's being widely sold, stolen, and hacked. And you don't know it.

It's full of mistakes that keep getting copied and pasted, and that you can't edit.

You are/will be generating more of it, but it's homeless.

Your medical privacy is precious.

The only way it can be made secure is to be decentralized.

It is legally owned by doctors and hospitals.

Hospitals won't or can't share your data ("information blocking").

Your doctor (>65 percent) won't give you a copy of your office notes.

You are far more apt to share your data than your doctor is.

You'd like to share it for medical research, but you can't get it.

You have seen many providers in your life; no health system/ insurer has all your data. Essentially no one (in the United States) has all their medical data from birth throughout their life.

Your electronic health record was designed to maximize billing, not to help your health.

You are more engaged and have better outcomes when you have your data.

Doctors who have given full access to their patients' data make this their routine.

It requires comprehensive, continuous, seamless updating.

Access to or "control" of your data is not adequate.

~10 percent of medical scans are unnecessarily duplicated due to inaccessibility.

You can handle the truth.

You need to own your data; it should be a civil right.

It could save your life.

mature medicine

11 January 2021

PREDICT 1 UK cohort



Microbiome data

8.8 average 2.2 s.d. Gb/sample 58.3 average 14.6 s.d. million reads/sample						
Taxonomic	Functional	Assembly	Antib			
746 species 29 spp. 90% prevalent 95 spp. 50% prevalent	UniRef90 1,910,069 UniRef50 878,520 KEGG knockouts 6,163	48,181 MAGs 29,035 MQ	3 F. Lipop apoli risk s			
176 spp. 20% prevalent	Pathways 445	19,146 HQ	fatty			



NIH's 'precision nutrition' bet aims for individualized diets

Effort will piggyback on giant genomics and health program

By Jocelyn Kaiser

here's no one-size-fits-all diet. If you want to avoid spiking your blood sugar with a snack, a banana may seem like a better choice than a sugary cookie. But some people in a 2015 study of 800 Israeli volunteers got their biggest blood sugar spike from bananas or bread instead of from sugar-laden baked goods. And as nutrition scientist Elizabeth Parks of the University of Missouri, Columbia, notes, "We all know people who lose weight easily, and others who don't."

Now, the U.S. National Institutes of Health (NIH) is making a major push to understand these individual differences. Last week, the agency announced what it calls the largest study yet to probe "precision nutrition," a \$156 million, 5-year effort to examine how 10,000 Americans process foods by collecting data ranging from continuous blood glucose levels to microbes in a person's gut.

The study "has the potential to truly transform the field of nutrition science," generating new tools, methods, and "a wealth of data to fuel discovery science for years to come," Griffin Rodgers, director of the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), said last year at an NIH board meeting where he

552 5 FEBRUARY 2021 • VOL 371 ISSUE 6529

introduced the project. Ultimately, it might enable nutritionists to tailor diets to an individual's genes and microbiome.

It is part of a broader push at NIH to boost nutrition science, a field sometimes viewed as "fuzzy" because "we are freerange eaters" and our diets are hard to control, notes Paul Coates, vice president of the American Society for Nutrition, who headed NIH's dietary supplements office until he retired in 2018.

In May 2020, NIH Director Francis Collins released the agency's first-ever 10-year strategic plan for nutrition science, acknowledging the importance of diet in chronic diseases such as heart disease and diabetes. The plan aims to fold in basic disciplines such as neurobiology, study the role of diet throughout life, consider how food can serve as medicine, and elevate precision nutrition. The concept recognizes that how the human body responds to food depends on factors from genetics to sleep habits, social environment, and gut microbes. For example, the Israeli study that found individual differences in the response to refined

sugar versus fruit showed the microbiome w s lar, ely responsible. Yow comes NUI's Mutrition for Presision of h, which w links, ack in All of A massive new National Institutes of Health precision nutrition study will give some volunteers controlled meals, like this one being prepared by a dietician at the agency's metabolic research kitchen. study, which has fully enrolled 272,000 of a

study, which has fully enrolled 272,000 of a planned 1 million participants, more than 50% from minority groups. "We realized it would be a really great fit" to take advantage of the All of Us data and infrastructure, says Holly Nicastro, a study coordinator and program director at NIH's nutrition office. Some 10.000 All of Us participants who

The New Hork Times join the nutrition study will wear various monitors to track physical activity, blood sugar, and more; record what they eat; and visit a clinic to consume a specific meal and undergo clinical tests. A subset of up to 1500 will also follow three different diets at home or in the clinic, and then have the same tests. And 500 to 1000 volunteers will live at a clinical center for three 2-week stretches while eating three tightly prescribed diets. Such "controlled feeding" studies are the field's gold standard, but their high cost usually keeps them small. NIH has recently conducted some in its clinical center to explore, for example, the effects of ultraprocessed foods, but they involved only 20 people.

By collecting a wide range of personal data, from participants' DNA makeup to their ZIP code, "we are removing a lot of that 'noise' that we had for years, created by the factors that we were not measuring before," says Tufts University nutrition scientist José Ordovás who, with Parks, cochaired a workshop last month to discuss the study. Artificial intelligence researchers will then use the collected data to create models that predict the best diet for an individual-an effort pioneered by the Israeli study, which spun off a company that developed an algorithm to tailor diets for people who are diabetic or trying to lose weight. A second, 5-year phase could test those models in clinical trials.

NIH is now inviting proposals for study components such as a data center, clinical centers, and a microbiome center. The aim is to begin enrolling volunteers by January 2023. "There's so much excitement" about the study, Parks says.

She and other nutritionists also welcome other signals of NIH's new focus. Its Office of Nutrition Research, once part of the NIH director's office, was demoted years ago to NIDDK. Last month, Collins announced it has been restored. Coates hopes that will mean a larger staff—the office now has just six people—and a modest budget to cofund studies with NIH institutes. "A lot [of nutritin science] falls between the cracks," he

savs−gaps he now hopes will close.

sciencemag.org SCIENCE

he A.I. Diet

layReview

SUNDAY MARCH 2 201

rget government-issued food ramids. Let an algorithm tell you what to eat.

A cardiologist and the author of the forthcoming "Deep Medicine," from which this essay is adapted.

OME months ago, I participated in a two-week experiment that involved usimage as martphone app to track every "markel of old 1 ace, every bevrage i dramk "the straight of the straight of the straight and I sent in a sample of my straight of the straight re than a thousand other people, was analyzed by pence to create a personalized diet algorithm. The out whak kind food al should be easing to live a longer

the sweets category: Cheesecake was given an A grade, t fig bars were a C -. In fruits: Strawberries were an A+ for

Continued on Pages

The Virtual Medical Assistant



Social, behavioral Genomics and omic layers Biosensors Immune system Gut microbiome Anatome Environmental Physical activity, sleep, nutrition Medication, alcohol, drugs Labs, plasma DNA; RNA Family history Communication, speech Cognition, state of mind All medical history World's medical literature, continually updated



7 Jan 2019



PRINCIPLED ARTIFICIAL INTELLIGENCE

A Map of Ethical and Rights-Based Approaches to Principles for AI

BERKMAN

KLEIN CENTER

FOR INTERNET & SOCIETY AT HARVARD UNIVERSITY

Privacy Accountability

>

- Safety and Security
- Transparency and Explainability Fairness and Non-discrimination Human Control of Technology Professional Responsibility Promotion of Human Values



mature medicine





RHEUMATISM IN MINERS

PART II: X-RAY STUDY

BY

J. H. KELLGREN and J. S. LAWRENCE

From the Walkden Miners' Clinic and the Rheumatism Research Centre, Manchester University

Brit. J. industr. Med., 1952, 9, 197.

KLG (Kellgren-Lawrence Grade) explained only 9% racial disparity in pain Deep neural net 43% (~5X)

Algorithms see causes of knee pain in Black patients, that human radiologists miss.

13 January 2021



Use of artificial intelligence for image analysis in breast cancer screening programmes: systematic review of test accuracy

"In retrospective test accuracy studies, 94% of AI systems were less accurate than the original radiologist, and all were less accurate than original consensus of two radiologists."

	Risk of bias						Applicability concerns			
Study reference	Patient selection	Index test	Comparator test	Reference standard	Flow and timing	Patient selection	Index test	Comparator test	Reference standard	
Standalone Al s	ystems (5 stud	ies)								
Lotter 2021 ²⁸	High	High	High	Unclear	Unclear	High	High	High	High	
McKinney 2020 ²⁹	High	High	Low	High	High	High	High	High	Low	
Rodriguez-Ruiz 2019 ³³	High	High	High	Unclear	Unclear	High	High	High	Unclear	
Salim 2020 ³⁵	High	High	Low	High	High	High	High	Low* High*	High	
Schaffter 2020 ³⁶	Low	High	Low	High	High	Unclear	High	Low* High*	High	
Al as reader aid	(3 studies)									
Pacilè 2020 ³⁰	High	High	High	High	Unclear	High	High	High	High	
Rodriguez-Ruiz 2019 ^{32,34}	High	High	High	High	Unclear	High	High	High	High	
Watanabe 2019 ³⁷	High	High	High	Unclear	Unclear	High	High High		Low	
Al for triage (4 s	tudies)									
Balta 2020 ²⁵	Low	High	None	High	High	Low	High	None	High	
Dembrower 2020 ²⁶	High	High	None	Low† High†	High	High	High	None	Low† High†	
Lång 2020 ²⁷	Low	High	None	High	High	Low	High	None	High	
Raya-Povedano 2021 ³¹	Low	Low	Low	Low	High	Low	High	High	Low	



Freeman K et al, August 2021



Artificial intelligence / Machine learning

Hundreds of Al tools have been built to catch covid. None of them helped.

Some have been used in hospitals, despite not being properly tested. But the pandemic could help make medical AI better.

Check for updates

world view



If You Don't Trust A.I. Yet, You're Not Wrong July 30, 2021



The New York Times



Al in medicine must be explainable

Al algorithms used for diagnosis and prognosis must be explainable and must not rely on a black box.

machine intelligence AI to diagnosis COVID via Chest X-rays and CT scans



Systematic review of 62 (out of 2,212) papers: Not 1 met criteria

- -Sufficiently documented manuscript describing a reproducible method
- -A method that follows best practice for developing a ML model
- -Sufficient validation to justify wider applicability

'Frankenstein' datasets

"None of the models identified are of potential clinical use due to methodologic flaws and/or underlying biases"

Multi-Dimensional Artificial Intelligence: Medical Applications

	WGS/PRS	Sensors	EHR	Microbiome	Labs/Scans	Environmental	Customized
Pandemic surveillance	+	+	+			+	+
Digital clinical trials	+	+	+	+	+	+	+
Rapid WGS diagnosis	+	+	+	+	+	+	+
Remote monitoring	+	+	+		+	+	+
Digital twin resource	+		+		+	+	+
Virtual health assistant	+	+	+	+	+	+	+









TUESDAY, APRIL 16, 2019 D1



GLOBAL HEALTH | DONALD G. McNEIL Jr.

Scanning a Better Future



The Butterfly, a hand-held ultrasound device the size of an electric shaver, brings medical imaging to remote African villages, often for the first time.

> BUSHORO, UGANDA – Lying on a church pew with his arm over his head, 6-year-old Gor-

do you recommend?" Swollen iympi nodes, and looked tired and swollen iympi nodes, and looked tired and Licking a soccer ball made of rags and twine, he clung weakly to his mother: This battery jowered and con-tism on the Phone's screen suggested his hum hund in thema. He and approval, Mr though the second approval, Mr the

Muhumuza prescribed an antibiotic, and or-dered blood tests to rule out tuberculosis, team.) malaria and H.I.V. He arranged for Gordon and his mother to get a ride to a local clinic Group and his mother to get a ride to a local clinic

customers are doctors and nurses who can afford a \$2,000 device that fits in a coat slowly swept a small ultrasound scamter up and down his chest. Dr. Cherniak and Rodgers Ssekawok Muhumuza, Hu Gugandar clinical officer he was training, stared at the IPhone into Gordon's lung expand and contract. -O.K. - Die Cherniak stang by sub-sub drives and the scant and the Cherniak hone by Cherniak hone







mature medicine

Double-outlet right

ventricle

An ensemble of neural networks provides expert-level prenatal detection of complex congenital heart disease



13 May 2021







The Topol Review

Preparing the healthcare workforce to deliver the digital future



Using a conservative estimate of

one (

saved per patient consultation

Annually, that equates to approximately







one million hours of outpatient clinic time



5.7 million hours of GP consultation time


THE NEW YORK TIMES BESTSELLER

THINKING,

FAST AND SLOW



DANIEL

KAHNEMAN

WINNER OF THE NOBEL PRIZE IN ECONOMICS

"[A] masterpiece . . . This is one of the greatest and most engaging collections of insights into the human mind I have read." —WILLIAM EASTERLY, *Financial Times*

MEDICINE,

FAST and SHALLOW



The Gift of Time

The Gift of Time

Keyboard Liberation

Synthesis of the patient's data Primary/screening review of all images Automated (doctorless) diagnosis of routine, non-serious conditions

Streamlining of workflow

Patient's virtual medical coach

Perchance to Think

Danielle Ofri, M.D., Ph.D.

MARCH 28, 2019

The NEW ENGLAND JOURNAL of MEDICINE

If it requires thinking, I'm sunk. This is an embarrassing admission for a field that prides itself on intellectual rigor. But with the frenetic pace of medicine today, there's no time or space (or reimbursement) for cogitation. We end up over-ordering tests because it feels more workable in the moment. We over-refer to specialists because we don't have the mental bandwidth to integrate confounding data. Beyond the financial waste, modern medical practice is a petri dish for medical error, patient harm, and physician burnout.



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There's No Algorithm For Empathy

When physicians rely on a behavioral "recipe" to convey empathy, patient care can suffer. BY HANNAH B. WILD

NARRATIVE MATTERS

pounding pharmacy. There is no formu-

la for empathy. There is no equation for

how to understand an individual pa-

tient's experience of their condition

and no script for how to respond in a

genuine manner that takes this into ac-

Compassion is not a com-

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count.



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THE CARE OF THE PATIENT* tice of medicine in its broadest sense includes the whole ___FRANCIS W. PEABODY. M.D. is bought dearly. Time, sympathy and understanding must be lavishly dispensed, but the reward is to be found in that personal bond which forms the greatest satisfaction of the practice of medicine. One of the essential qualities of the clinician is interest in humanity, for the secret of the care of the patient is in caring for the patient.

> that requires continued study and prolonged experience disease may be entirely impersonal; the care of a patient in close contact with the sick. All that the medical must be completely personal. The significance of the school can hope to do is to supply the foundations on intimate personal relationship between physician and which to build. When one considers the amazing progress of science in its relation to medicine during the extraordinarily large number of cases both diagnosis last thirty years, and the enormous mass of scientific and treatment are directly dependent on it, and the material which must be made available to the modern failure of the young physician to establish this relaphysician, it is not surprising that the schools have tionship accounts for much of his ineffectiveness in tended to concern themselves more and more with this the care of patients. phase of the educational problem. And while they have been absorbed in the difficult task of digesting and correlating new knowledge, it has been easy to overlook the fact that the application of the principles of highest human ideals, are apt to deteriorate into dehu-

* One of a series of talks before the students of the Harvard Medical School on "The Care of the Patient."

a profession to be entered. It is an ever widening field the crux of the whole situation. The treatment of a patient cannot be too strongly emphasized, for in an

science to the diagnosis and treatment of disease is only one limited aspect of medical practice. The prac-

INSTRUCTION IN TREATMENT OF DISEASE

Hospitals, like other institutions founded with the manized machines, and even the physician who has the patient's welfare most at heart finds that pressure of

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