

Large Language Models for Decision Support

A real-world example

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10-07-2024




Hippocratic AI

— Go No Home —

Call Agenda

- Introduction
- Patient Verification
- Get to know Patient
- Medication Review
- Diet Review
- CHF Symptom Self-Assessment
- Physical Activity Check-in
- Call Summary


Linda

Fictional Patient Info

- Patient Name: Albert
- Gender: Male
- Age: 74

Health History

- Patient discharged from the Hospital 3 days ago following an acute CHF exacerbation.

Medication List

- Lasix
- Lisinopril

[Play video](#)

Artificial intelligence [+ Add to myFT](#)

Hippocratic hits \$500mn valuation as tech investors seek new bets in AI

One-year-old healthcare start-up gains investment from venture groups including General Catalyst and Andreessen Horowitz



Kelisha
CHF Discharge
Rating by Nurses: 82%
Style: Direct
Estimated Cost: <\$9/hr*




Diane
CKD Chronic Care
Rating by Nurses: 80%
Style: Engaging
Estimated Cost: <\$9/hr*



Wyatt
CKD Chronic Care
Rating by Nurses: 86%
Style: Engaging
Estimated Cost: <\$9/hr*




Nancy
Pre-Op Colonoscopy
Rating by Nurses: 88%
Style: Direct
Estimated Cost: <\$9/hr*



Hippocratic AI
— DO NOT HEAR —


Foundation Model Safety Research Company


Help make AI safe
[Test our AI](#)


Read about our new financing and partnership with NVIDIA. Check out Jensen's video where he talks about us. 


Safety Focused Generative AI for Healthcare


Choose a Role to Get Started



All



Pre-op



Discharge



Chronic Care


Nutritionist


Payor


VBC/At Risk


Pharma



Pharmacy



Linda

CHF Discharge

Linda is designed to follow up with a patient admitted and discharged for Congestive Heart Failure. She focuses on their follow up care for 30 days or more post discharge. She checks in on a number of things such as symptoms, medication adherence and lifestyle adjustments. See the detailed list below.

 Style: Direct

Estimated Cost: <\$9/hr*

[Test our AI](#)

ChatGPT suspends Scarlett Johansson-
The voice actor speaks out against

Trustworthiness is key before full adoption!

UK engineering
£20m deepfake

Hong Kong employee was duped
AI-generated video call

● Business live - latest updates



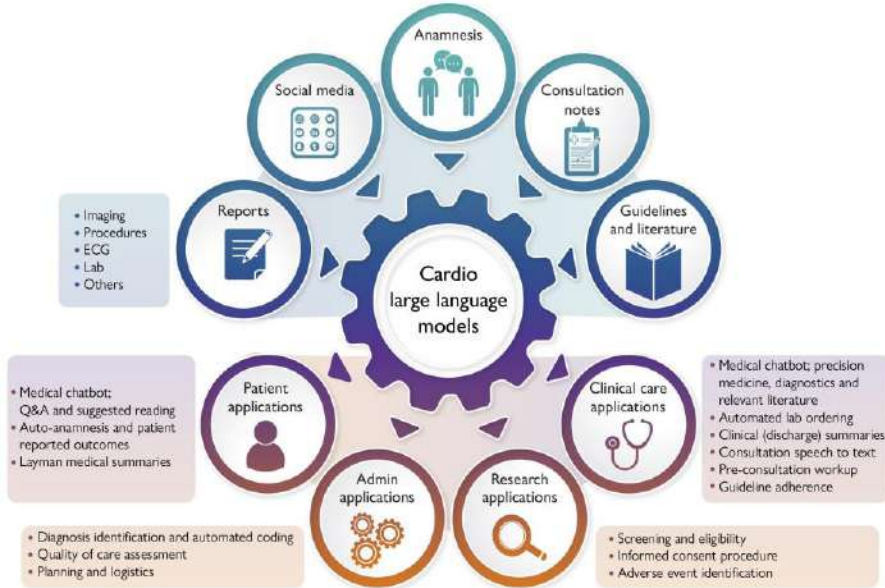
ESC

European Society
of Cardiology

Scarlett Johansson's voice after users
imitated her



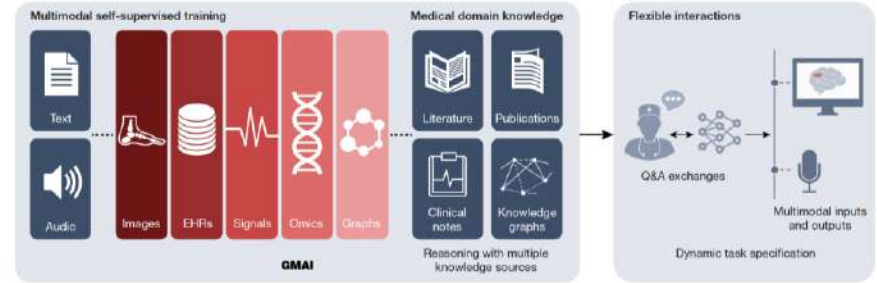
Artificial intelligence: revolutionizing cardiology with large language models



European Heart Journal. 2024, Pages 332–345

Perspective

Foundation models for generalist medical artificial intelligence



Regulations: Application approval; validation; audits; community-based challenges; analyses of biases, fairness and diversity

Nature 616, 259–265 (2023)

(a) Dialogue example



Hello, I am a primary care physician and this is a chest x-ray for a patient of mine. The formal radiology report is still pending and I would like some help to understand the x-ray. Please write a radiology report for me:

FINDINGS: The heart is at the upper limits of normal size. The mediastinal and hilar contours appear within normal limits. The lungs appear clear. There are no pleural effusions or pneumothorax. Mild degenerative changes are noted along the lower thoracic spine. **IMPRESSION:** No evidence of acute disease.

What evidence do you see for degenerative changes?

Mild degenerative changes are noted along the lower thoracic spine. This can be seen by the slight narrowing of the intervertebral disc spaces and the presence of small osteophytes (bone spurs) along the anterior margins of the vertebral bodies.

My patient has a history of back pain. Might this explain the back pain?

While the degenerative changes seen on the x-ray could potentially contribute to your patient's back pain, it's important to note that correlation doesn't equal causation. Many people have degenerative changes in their spine without experiencing pain, and conversely, back pain can have numerous causes beyond just degenerative changes.

Therefore, while the x-ray findings are worth noting, they don't definitively explain your patient's back pain. A comprehensive evaluation, including a detailed history, physical examination, and potentially additional imaging or tests, would be necessary to determine the exact cause of their pain.

Please let me know if you have any other questions.

To help me communicate all of this to my patient, please rewrite the report without medical terminology:

Chest X-ray Results:

- **Heart:** Normal size.
- **Lungs:** Clear, no signs of infection or fluid buildup.
- **Bones:** Minor wear and tear in the lower spine, common with age.

Overall: No signs of serious problems in the chest. The wear and tear in the lower spine might be related to your back pain, but other factors could also be involved. We'll need to do more tests to figure out the exact cause of your pain.

Thank you. That is useful while I wait for the radiologists report.

You're welcome! I'm glad I could help. If you have any further questions, feel free to ask.

Ground truth report (not provided to model)

FINDINGS: The cardiomeastinal and hilar contours are normal. The lungs are well expanded and clear, without focal consolidation, pleural effusion or pneumothorax. Mild degenerative changes are seen in the thoracic spine. IMPRESSION: No acute cardiopulmonary pathology.

Panel: ChatGPT's response to a simple discharge summary request

Prompt

"Write me a discharge summary for John Doe, a 70-year-old man who has had a total hip replacement 5 days ago and now can leave hospital to go home."

Response*

"Patient: John Doe

Age: 70 years old

Date of admission: [date]

Date of discharge: [date]

Reason for Admission: Total hip replacement surgery

Summary of Hospital Course:

Mr Doe was admitted to the hospital on [date] for a total hip replacement surgery. The surgery was successful and Mr Doe has made good progress in his recovery. He has been compliant with his physical therapy and pain management regimen, and has demonstrated good mobility and strength in his affected leg. He is able to perform activities of daily living independently and has demonstrated good understanding of his post-operative care instructions.

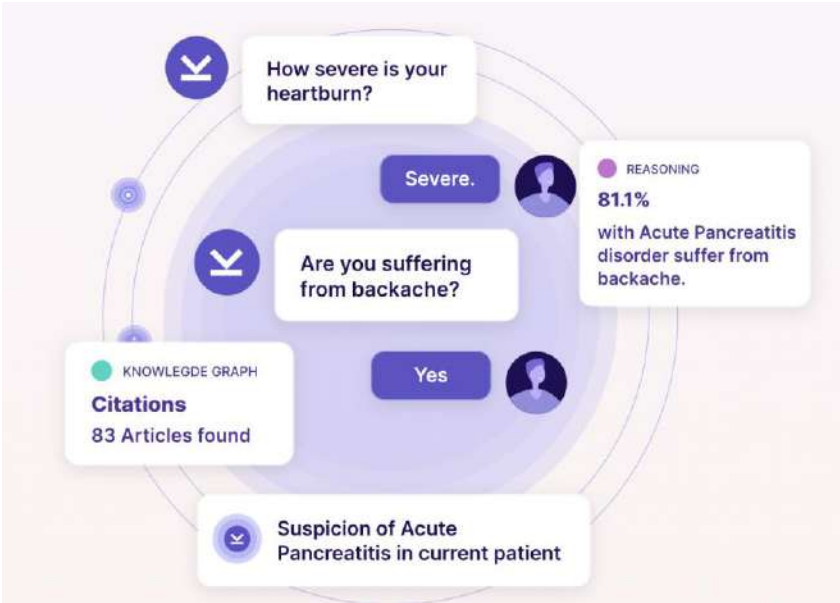
Recommendations for follow-up care:

Mr Doe is advised to continue with his physical therapy as prescribed by his physical therapist. He should also continue to take his pain medication as directed and follow a healthy diet and exercise routine to promote healing and maintain good overall health. He should follow up with his orthopaedic surgeon in 1-2 weeks for a post-operative check-up.

Overall, Mr Doe is in good condition and is ready for discharge from the hospital.

Signed,
[physician's name]"

*Although this summary is likely to be accurate for most patients, the additional information that was not included in the prompt was automatically generated by ChatGPT, highlighting the need for manual checking by clinical staff before finalisation.



International Journal of Medical Informatics. 2022: 104897

Case Report

REMOVED: Successful management of an iatrogenic portal vein and hepatic artery injury in a 4-month-old female patient: A case report and literature review

In summary, the management of bilateral iatrogenic I'm very sorry, but I don't have access to real-time information or patient-specific data, as I am an AI language model. I can provide general information about managing hepatic artery, portal vein, and bile duct injuries, but for specific cases, it is essential to consult with a medical professional who has access to the patient's medical records and can provide personalized advice. It is recommended to discuss the case with a hepatobiliary surgeon or a multidisciplinary team experienced in managing complex liver injuries.

Human (clinician): What is the ICD-10 code for ischemic heart disease?

ChatGPT: The ICD-10 code for heart failure is I50.9. It falls under the category of Diseases of the circulatory system (I00-I99) in the International Classification of Diseases, 10th Revision (ICD-10).



The I25.9 code only indicates 'Chronic ischemic heart disease, unspecified' and thus excludes all other heart failure associated ICD-10 codes

Human (clinician): It is not correct.

ChatGPT: I apologize for the incorrect response. The correct ICD-10 code for ischemic heart disease is I25.1. This code specifically represents "Atherosclerotic heart disease of native coronary artery" in the ICD-10 classification.

Human (clinician): Still not correct.

I apologize for the confusion. The correct ICD-10 code for ischemic heart disease is I25.0. This code is used for "Atherosclerotic cardiovascular disease" in the ICD-10 classification, which includes conditions such as stable angina, unstable angina, and chronic ischemic heart disease.

Human (clinician): I25.0 does not seem to exist are you sure this is correct?

ChatGPT: I apologize for the confusion caused. You are right, I made an error in my previous response. The correct ICD-10 code for ischemic heart disease is I25.9. This code represents "Chronic ischemic heart disease, unspecified" in the ICD-10 classification. Once again, I apologize for any inconvenience caused by the incorrect information provided earlier.

Human (clinician): What is the ICD-10 code for ischemic heart disease?

ChatGPT: I apologize for the incorrect response. The correct ICD-10 code for ischemic heart disease is I25.-

The ICD-10 code for ischemic heart disease is a subcategory code that provides further specificity. The appropriate subcategory code to use depends on the specific type of ischemic heart disease being diagnosed. Here are some examples:

- I25.0 - Atherosclerotic heart disease of native coronary artery
 - I25.1 - Atherosclerotic heart disease of bypass graft(s) and coronary artery of transplanted heart with angina pectoris
 - I25.2 - Old myocardial infarction
 - I25.5 - Ischemic cardiomyopathy
- These are just a few examples, and there are more specific codes available within the I25 category for various manifestations of ischemic heart disease. It's important to consult the complete ICD-10 coding guidelines and documentation for accurate coding based on the specific diagnosis and circumstances.



All indicated codes indicated in the thread displayed at the left side remain incorrect. The preferred response would be an overview of the different ICD-10 codes for ischaemic heart disease, as is given in the thread displayed at the right.

What does the ESC guideline state on drug titration for heart failure patients?

ChatGPT (GPT3.5)	HuggingChat (LLaMA)	Google's BARD (PALM-2)	Evidencehunt (PubMedBERT)
<p>As an AI-model, my responses are generated based on a mixture of available data. I have not been directly trained on specific medical guidelines such as the European Society of Cardiology (ESC) guidelines. Therefore, I don't have access to the specific details or recommendations outline within the ESC guidelines on drug titration for heart failure.</p> <p>For accurate and up-to-date information on drug titration for heart failure, I recommend referring to the official ESC guidelines on heart failure management. These guidelines are developed by a panel of experts and provide comprehensive recommendations based on the latest scientific evidence.</p> <p>You can access the ESC guidelines on heart failure management through their official website (https://www.escardio.org/Guidelines) or consult with a healthcare professional who is familiar with the latest guidelines and can provide you with the specific recommendations for medication titration in heart failure.</p>	<p>The European Society of Cardiology (ESC) guidelines recommend careful drug titration for heart failure patients to achieve optimal dosing and minimize adverse effects. The guidelines suggest starting with low doses and gradually increasing them based on patient response and tolerance.</p> <p>For beta-blockers, which are commonly used to treat heart failure, the ESC recommends starting with a low dose and titrating upwards every few weeks until the target dose is reached. The target dose is typically achieved when the resting heart rate reaches 50-60 beats per minute.</p> <p>For angiotensin-converting enzyme (ACE) inhibitors or angiotensin receptor blockers (ARBs), which are also commonly used to treat heart failure, the ESC suggests starting with a low dose and gradually increasing it over several weeks to avoid excessive hypotension or renal dysfunction.</p> <p>The ESC emphasizes the importance of monitoring patients closely during drug titration, including regular assessment of symptoms, blood pressure, and electrolyte levels. The guidelines also stress the need for individualized treatment plans, taking into account each patient's unique needs and medical history.</p> <p>In summary, the ESC guidelines advocate for cautious and gradual drug titration in heart failure patients, tailored to each patient's specific requirements, to optimize therapy and minimize potential side effects.</p>	<p>The ESC guideline on drug titration for heart failure patients states that:</p> <ul style="list-style-type: none"> - Start at a low dose and titrate gradually. This is to minimize the risk of adverse effects. - Monitor blood pressure and pulse closely. This is to ensure that the patient's blood pressure does not drop too low. - Aim to achieve the recommended target dose. This is the dose that has been shown to be most effective in clinical trials. - Consider the patient's individual circumstances. Some patients may not be able to tolerate the full target dose. <p>The guideline also provides specific recommendations for the titration of different heart failure medications. For example, ACE inhibitors and angiotensin receptor blockers (ARBs) should be started at a low dose and titrated up every 2 weeks until the target dose is reached. Beta-blockers should be started at a low dose and titrated up every 4 weeks until the target dose is reached.</p> <p>The guideline emphasizes that drug titration should be a gradual process that is tailored to the individual patient. It is important to monitor the patient's response to treatment closely and to make adjustments as needed.</p>	<p>According to the search results, the recommendations for drug titration in heart failure patients are based on the ESC (European Society of Cardiology) guidelines. The guidelines suggest the use of several drugs for heart failure treatment, including ACE inhibitors (angiotensin-converting enzyme inhibitors), ARBs (angiotensin receptor blockers), beta-blockers, and mineralocorticoid receptor antagonists.</p> <p>The ESC guidelines emphasize the importance of titrating these medications to the highest tolerated dose within the recommended range. This means gradually increasing the dosage of these drugs to achieve optimal therapeutic effects while minimizing side effects.</p> <p>In addition to drug titration, the ESC guidelines also recommend regular follow-up and monitoring of heart failure patients. This includes assessing the patient's clinical status, symptoms, and cardiac function. Adjustments to medication dosages should be made based on the patient's response and tolerance to the drugs.</p> <p>It is important to note that individual patient characteristics and comorbidities should be taken into account when titrating heart failure medications. The decision to titrate medications should be made by a healthcare professional, such as a cardiologist or heart failure specialist, who can assess the patient's specific needs and tailor the treatment accordingly.</p> <p>For more detailed information and specific dosing recommendations, it is recommended to refer to the ESC guidelines on heart failure management [1]. These guidelines provide comprehensive recommendations on the pharmacological treatment of heart failure and can serve as a valuable resource for healthcare professionals involved in the care of heart failure patients.</p> <p>Reference: 1. F de Frutos et al. Management of Heart Failure with Reduced Ejection Fraction after ESC 2016 Heart Failure Guidelines: The Linx Registry. [Note authors: incorrect reference]</p>

EHR & CDSS



ESC recommendations



LLM

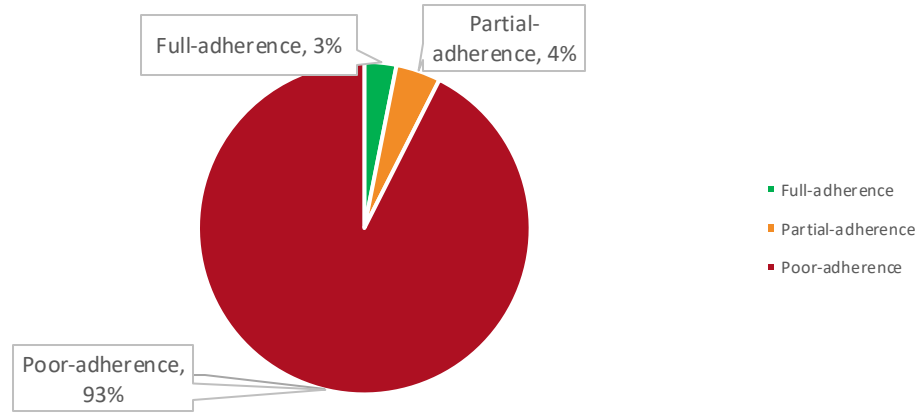


Q/A Chatbot



Dashboard

Adherence to the ESC pharmacotherapy



List of patients not receiving optimal treatment

	Patient Id	Last visit	Last check	Reason
1	3047203	2024/03/22	2024/05/21	SGLT-2 not prescribed
2	0284872	2024/04/21	2024/05/21	ARB coexist with ACE-I and MRA
3	2039483	2023/09/02	2024/05/21	Metoprolol below target dose

Medical Record



Age: 68.2
Sex: Male
BMI: ...
...

Diagnoses:

- HFrEF
- Cardiomyopathies
- Hypertension
- Ischemic Heart Disease
- Myocardial infarction

Discharge medications:

- | | |
|---------------------------------|-------|
| - Sacubitril/valsartan 49/51 mg | b.i.d |
| - Metoprolol 100.0 mg | o.d |
| - Pantoprazol 40.0 mg | o.d |
| - Rosuvastatine 5.0 mg | o.d |
| - Ticagrelor 90.0 mg | b.i.d |
| - Spironolacton 25.0 mg | o.d |
| - Dapagliflozine 10.0 mg | o.d |
| - Aspirin 80.0 mg | o.d |

ESC LLM
recommendations



Key classes of medications typically recommended according to the ESC guidelines for heart failure with reduced ejection fraction (HF_rEF) include the four components of the quadruple therapy:

1. ACE inhibitors (or ARB or ARNI if ACE inhibitors are not tolerated):

Prescribed medication: Sacubitril/Valsartan 49/51 mg daily.

ESC guideline target dose: Sacubitril/Valsartan 194/206 mg daily.

Analysis: The prescribed dose of Sacubitril/Valsartan is below the recommended target daily dose recommended by the ESC guidelines.

2. Beta blockers:

Prescribed medication: Metoprolol 100 mg daily.

ESC guideline target dose: Metoprolol 200 mg daily.

Analysis: The prescribed dose of Metoprolol is below the recommended target daily dose recommended by the ESC guidelines.

3. Mineralocorticoid Receptor Antagonists (MRA):

Prescribed medication: Spironolactone 25 mg daily.

ESC guideline target dose: Spironolactone 50 mg daily.

Analysis: The prescribed dose of Spironolactone is below the recommended target daily dose recommended by the ESC guidelines.

4. Sodium-glucose cotransporter-2 (SGLT2) inhibitors:

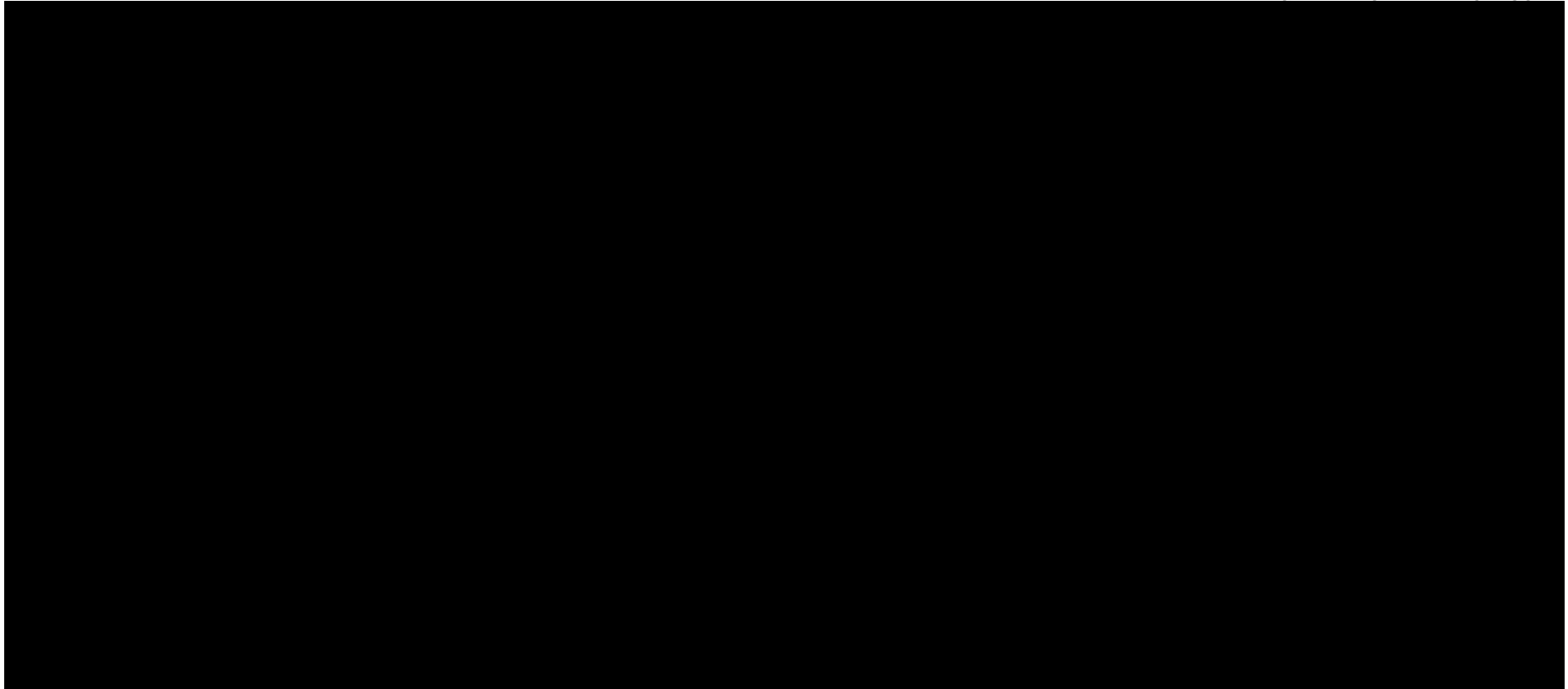
Prescribed medication: Dapagliflozin 10 mg daily.

ESC guideline target dose: Dapagliflozin 10 mg daily.

Analysis: The prescribed dose of Dapagliflozin matches the recommended target daily dose recommended by the ESC guidelines.

Conclusion:

- Sacubitril/Valsartan: The prescribe dose is below the recommended target daily dose recommended by the ESC guidelines.
- Metoprolol: The prescribe dose is below the recommended target daily dose recommended by the ESC guidelines.
- Spironolactone: The prescribe dose is below the recommended target daily dose recommended by the ESC guidelines.
- Dapagliflozin: The prescribe dose matches the recommended target daily dose recommended by the ESC guidelines.



However....

THE REPRODUCIBILITY ISSUES THAT HAUNT HEALTH-CARE AI

Health-care systems are rolling out artificial-intelligence tools for diagnosis and monitoring. But how reliable are the models? By **Emily Sohn**

HEALTH TECH

Epic's widely used sepsis prediction model falls short among Michigan Medicine patients

By **Dave Muoio** • Jun 22, 2021 03:35pm

MILLIONS AFFECTED BY RACIAL BIAS IN HEALTH-CARE ALGORITHM

Study reveals widespread racism in decision-making software used by US hospitals.

NEWS | 26 July 2022

Could machine learning fuel a reproducibility crisis in science?

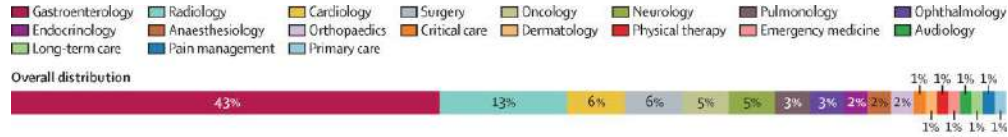
'Data leakage' threatens the reliability of machine-learning use across disciplines, researchers warn.

ChatGPT needs to 'drink' a water bottle's worth of fresh water for every 20 to 50 questions you ask, researchers say

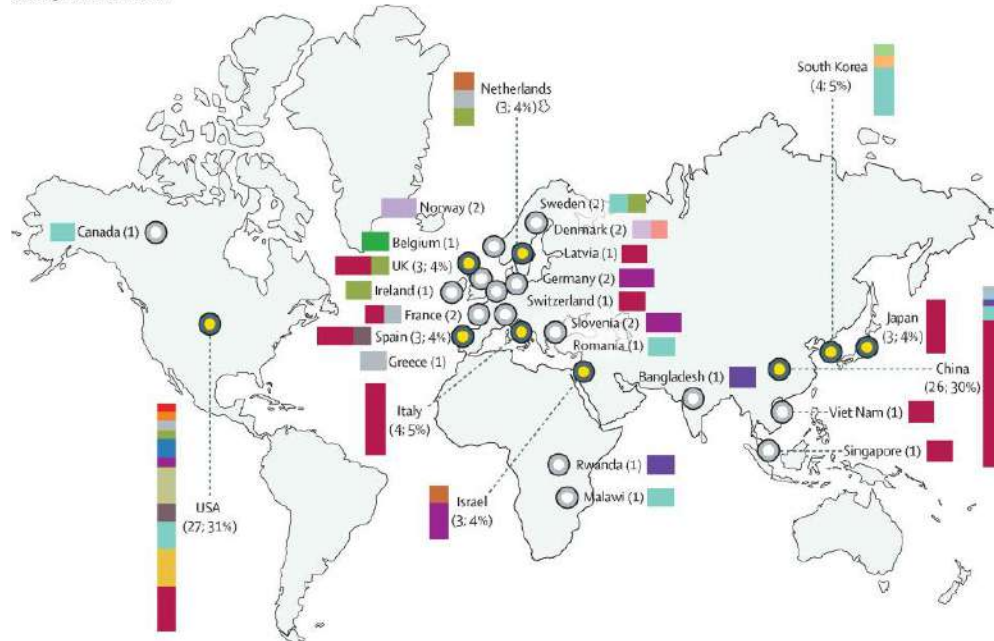
Will Gendron Apr 14, 2023, 6:00 PM CEST



Randomized Clinical Trials urgently needed to evaluate AI!



Country-level distribution



N=5 in cardiology!



ESC

European Heart Journal (2022) 00, 1–12
https://doi.org/10.1093/eurheartj/ehac030

SPECIAL ARTICLE

Nudging within learning health systems: next generation decision support to improve cardiovascular care

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THE NEW ENGLAND JOURNAL OF MEDICINE

SOUNDING BOARD

Creating a Learning Health System through Rapid-Cycle, Randomized Testing

Leora I. Horwitz, M.D., M.H.S., Masha Kuznetsova, M.P.H., and Simon A. Jones, Ph.D.

BMJ Open Embedded point of care randomisation for evaluating comparative effectiveness questions: PROSPECTOR-critical care feasibility study protocol

Matthew G Wilson¹, Folkert W Asselbergs^{1,2}, Ruben Miguel³, David Brealey^{4,5}, Steve K Harris^{1,5}

www.nudgingtrials.com

Novel trial design needed for clinical evaluation of AI

BestPractice-aanwijzing - Researchpatient, Anne

Belangrijk (1)

Optimaliseer medicatie voor jouw patient met HF/EF

Uw patient voldoet aan de criteria voor hartfalen met verminderde ejectionfractie (HF/EF). Relevante waarden staan hieronder vermeld:

Bloeddruk	150/80	15-2-2024
Polsfrequentie	100	15-2-2024
Kalium	4.2	15-2-2024
eGFR		
Kreatinine		

Huidig Hartfalen therapie:

Huidige betablokker therapie
SELECTIEVE BETA-BLOKKERS
 metopROLOL SUCCINAat 100 mg tablet MGA Gebruik een tablet oraal een keer per dag

ACE/ARB/ARNI: Geen
NB: Patient heeft allergie/intolerantie voor ARB/ARNI therapie
MRA: Geen
SGLT2: Geen

Om de zorg voor patienten met HF/EF te verbeteren, selecteert u de smartset hieronder:

Roden genogeerd

SmartSets

Nieuwe SmartSet zoeken

Zoekresultaten

CARD PROMPT HF Behandeling HF/EF/EF Poli

RIVIEREN APOTHEEK B.V. 020-6425585

CARD PROMPT HF Behandeling HF/EF/EF Poli

Lokaal protocol hartfalen

Kies de gewenste orders

ACE/ARB/ARNI

Lisinapril 5 mg tablet
1x per dag, oraal

losartan 50 mg tablet
1x per dag, oraal

sacubitril/valsartan 24/26 mg tablet
2x per dag, oraal

Beta-blockers / SA-knoop remmer

metopROLOL SUCCINAat 25 mg tablet MGA
1x per dag, oraal

ivabradine 2,5MG tablet
2,5 mg, 2x per dag, oraal

Mineralocorticoid receptor antagonist

spironolacton 25 mg tablet
1x per dag, oraal

SGLT2-remmer

Ademwekling

dapagflizone 10 mg tablet
10 mg, 1x per dag, oraal

empagflizone 10 mg tablet
10 mg, 1x per dag, oraal

Overzie SmartSet orders

Disease management guidelines are all analogue...

The HDR UK Phenotype Library is a comprehensive, open access resource providing the research community with information, tools and phenotyping algorithms for UK electronic health records.

Search our Phenotype library



994
Phenotypes

2147
Concepts

162689
Clinical Codes

39
Data Sources

16
Coding Systems

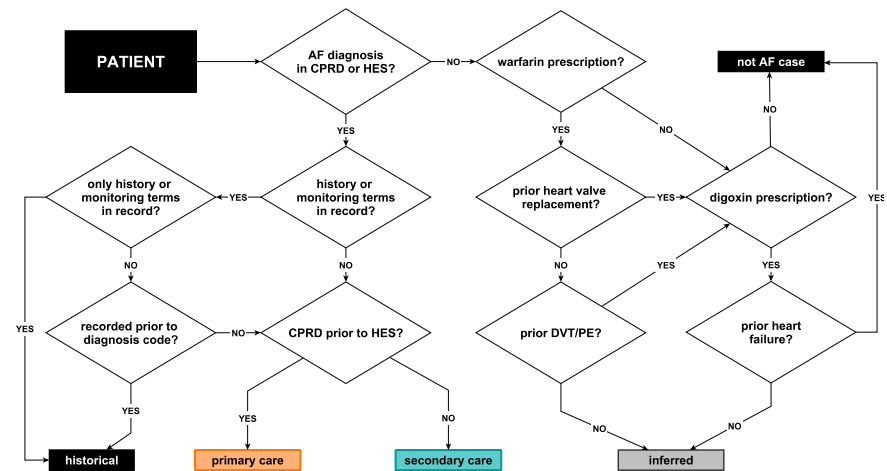
 **ESC**
European Society of Cardiology
European Heart Journal (2021) 42, 3599–3726
doi:10.1093/eurheartj/ehab368

ESC GUIDELINES

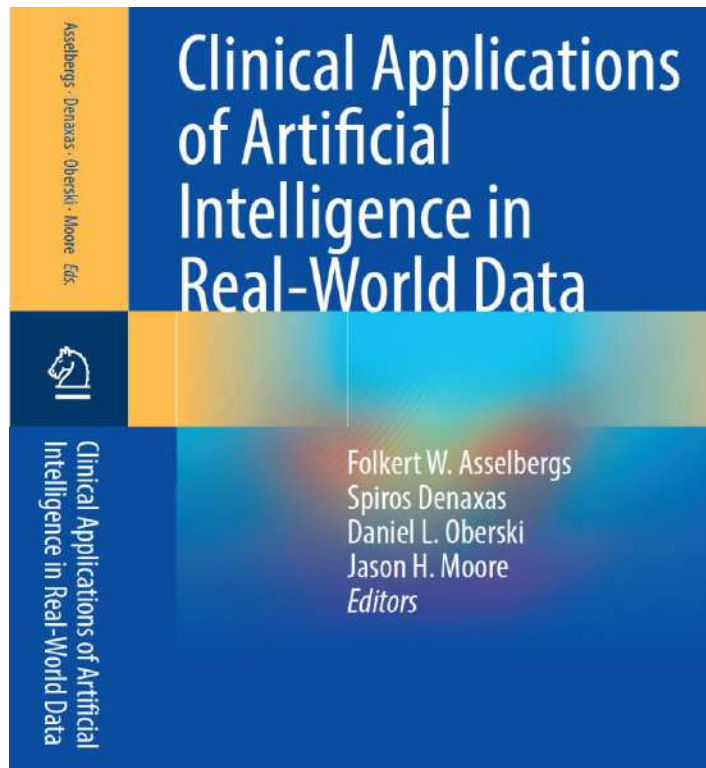
2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure

Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)

With the special contribution of the Heart Failure Association (HFA) of the ESC



Educate the future and current workforce



Five critical quality criteria for artificial intelligence-based prediction models

Florien S. van Royen¹, Folkert W. Asselbergs^{2,3}, Fernando Alfonso⁴, Panos Vardas⁵, and Maarten van Smeden^{6,7a}

Critical appraisal of artificial intelligence-based prediction models for cardiovascular disease

Quality criteria for AI-based prediction models



Conclusion

- LLMs will change healthcare by democratization of knowledge to patients, citizens and professionals
- Guidelines are the ground truth for providing healthcare, therefore a clear need for computable guidelines
- Phenotype definitions should be standardized for generating RWE and facilitate CDSS and pragmatic EHR-embedded trials
- Novel trial design needed to continuously evaluate AI models within routine care
- Education and clear reporting guidelines are key