

Bridging the Gap:

How Clinical Language Models can support Data Exchange and Interpretation between Primary Care Centers and Hospitals

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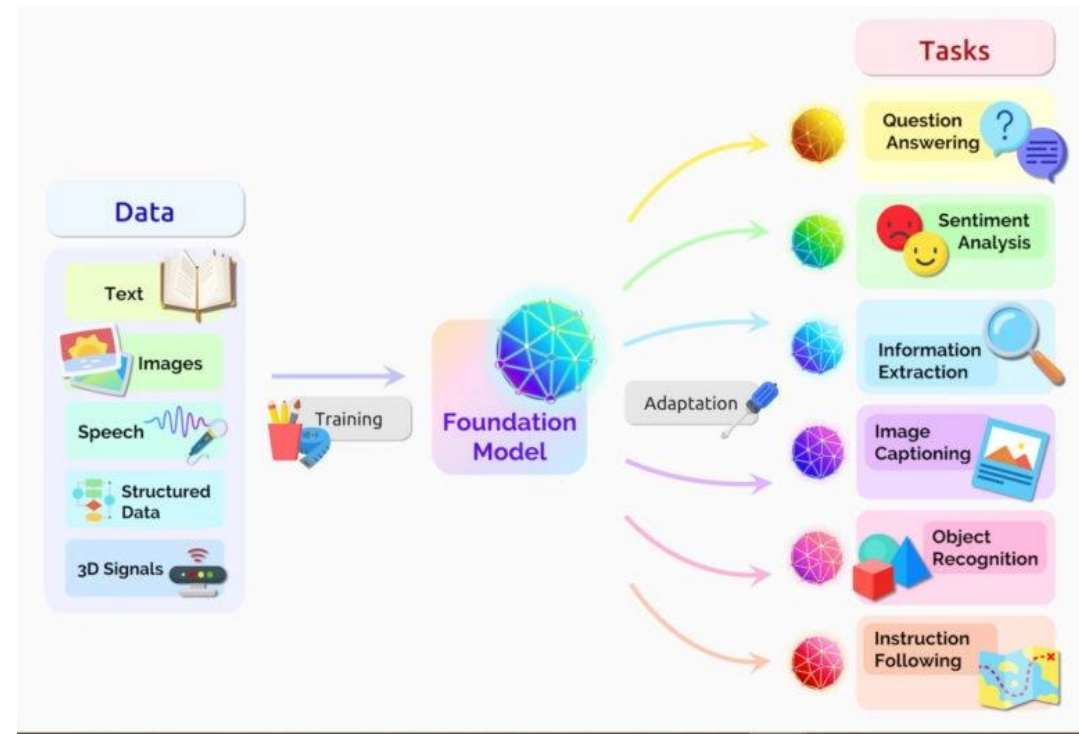
Clinical Language Models

Purpose

- Specialized clinical models outperform large language models (LLMs) trained on general text for parsing and reasoning over electronic health records (Yang X. et al., 2022)
- Smaller clinical models prove to be more efficient and effective, even when fine-tuned with limited annotated data (Lehman E. et al., 2023)
- Pretraining on clinical tokens allows for the development of parameter-efficient models that match or outperform larger LLMs trained on general text (Jiang L.Y. et al., 2023)
- Prompt tuning is a parameter-efficient technique for aligning LLMs with the medical domain (Singhal K. et al., 2023)
- The research findings emphasize the value of domain-specific language models for healthcare applications and provide code and models for further exploration.

How does a LLM work?

- **Word Predictions:** LLMs estimate the probability of a word or token given a context. For example, after the phrase "The cat is chasing the ...", the model might assign a high probability to the word "mouse" based on its training.
- **Sampling and Diversity:** LLMs can sample words based on their predicted probabilities. This allows for diverse outputs; for instance, sometimes it might complete i.e. with "squirrel" or "dog", depending on the probabilities and sampling method.
- **Fine-tuning and Task Optimization:** When LLMs are fine-tuned for specific tasks, they adjust their internal parameters to optimize the likelihood of the training data. This essentially means they're learning to make their predictions more probable for the given task-specific data.



Language Models

Trained to predict the next word in a sentence:

The cat is chasing the _____

dog 5%
mouse 70%
squirrel 20%
boy 5%
house 0%

How does a CLM work?

Step a - Data collection

Collection of unannotated clinical records and task-specific annotated clinical records which originate from the entire hospital system, encompassing a wide-ranging patient demographic from various clinical departments.

Step b - Pretraining

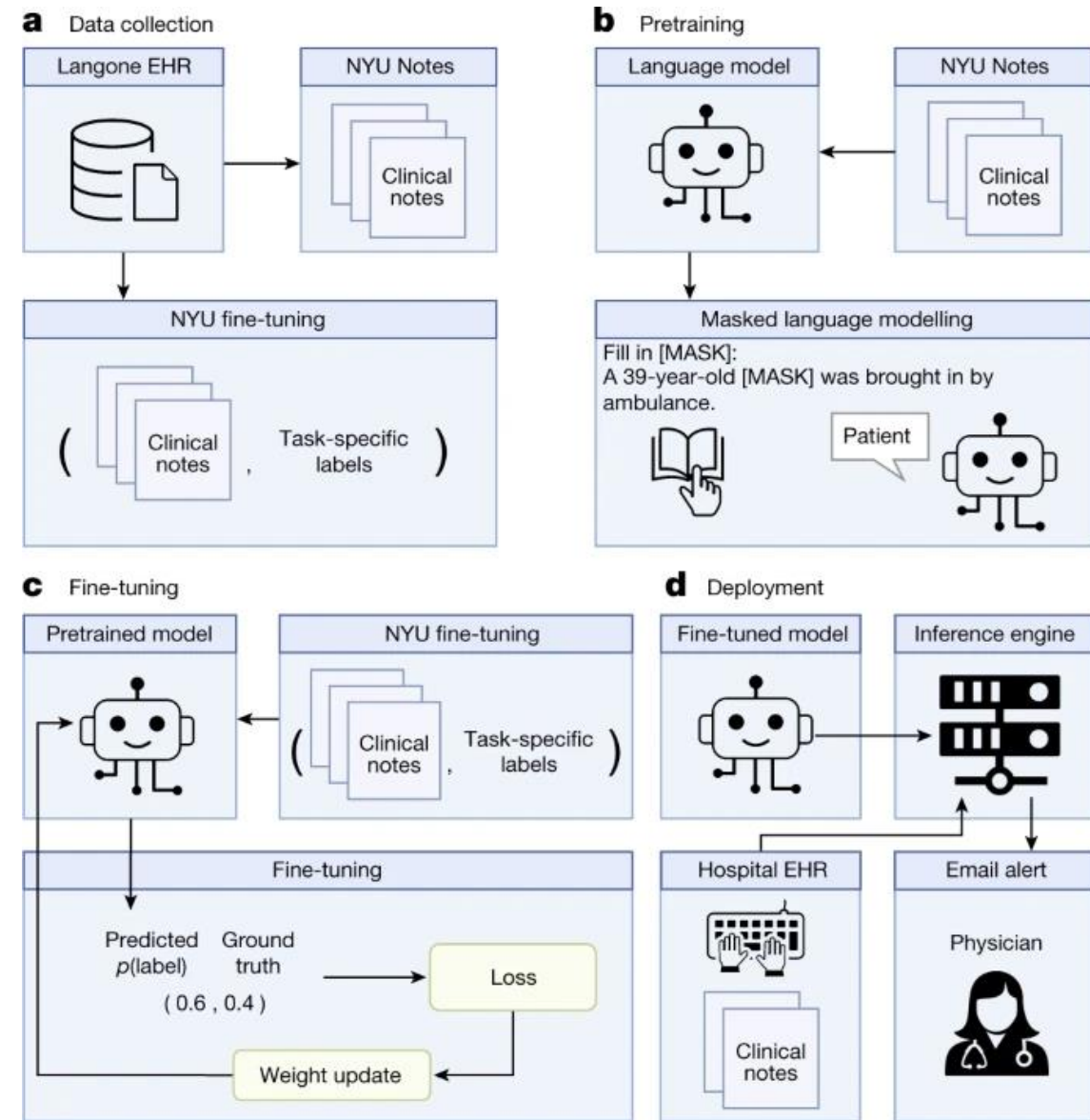
Pretraining of an adapted LLM on the entire record data set to create a CLM model for medical language contained within the EHR.

Step c - Fine-Tuning

Performing fine-tuning for particular tasks i.e. predicting 30-day all-cause readmission and assessing the performance using separate retrospective data.

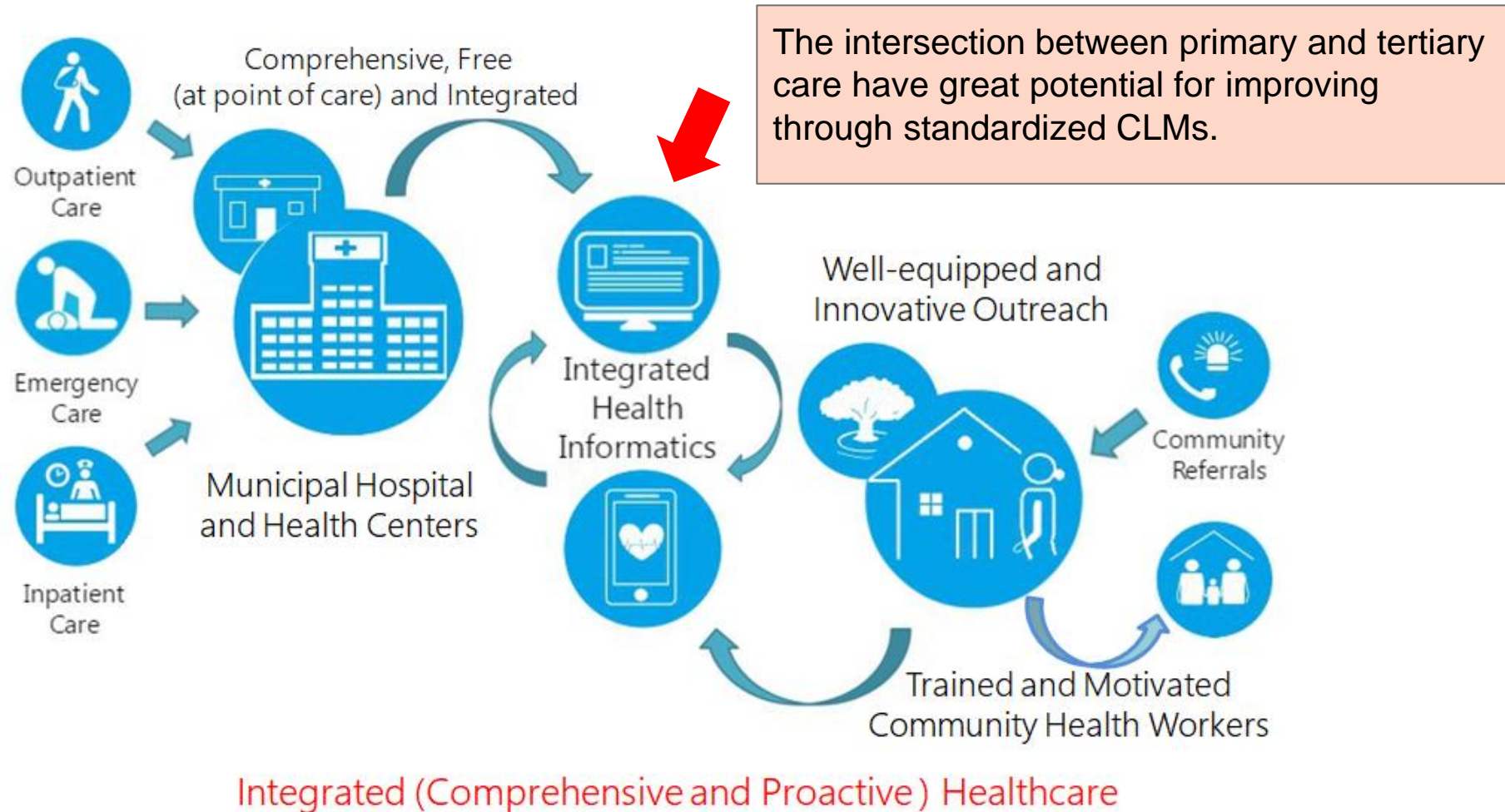
Step d - Deployment

Compression to optimize model, implementation into an inference engine that interacts with the EHR system, where it reads notes as soon as they are typed by physicians.



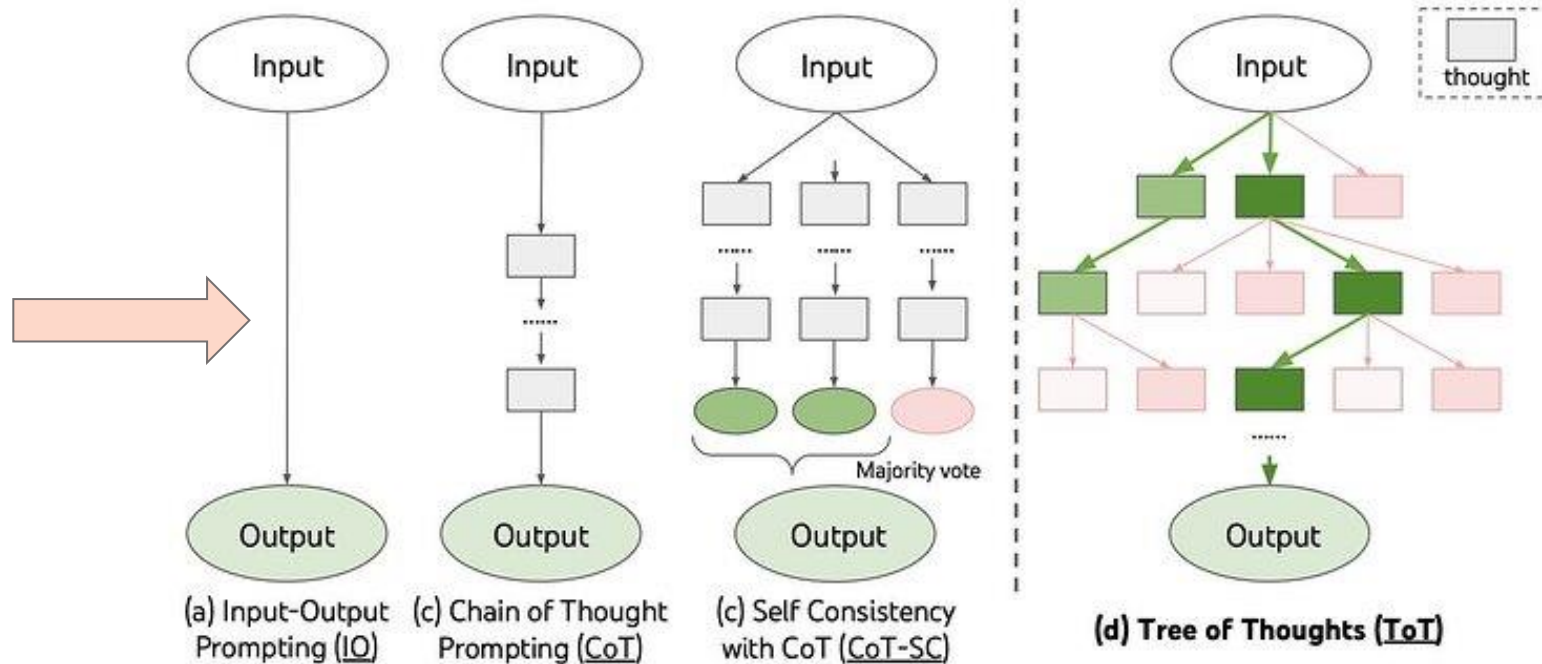
Jiang, L.Y., Liu, X.C., Nejatian, N.P. et al. Health system-scale language models are all-purpose prediction engines. *Nature* 619, 357–362 (2023). <https://doi.org/10.1038/s41586-023-06160-y>

CLMs for Primary Care Medicine and Hospital Care



“Prompting” or “How to talk to a CLM”

Input Output Prompting is the most fundamental method of interacting with a language model. This method involves providing the model with a specific task and, optionally, defining the desired format of the output. “Write an anamnesis based on the following data ...”

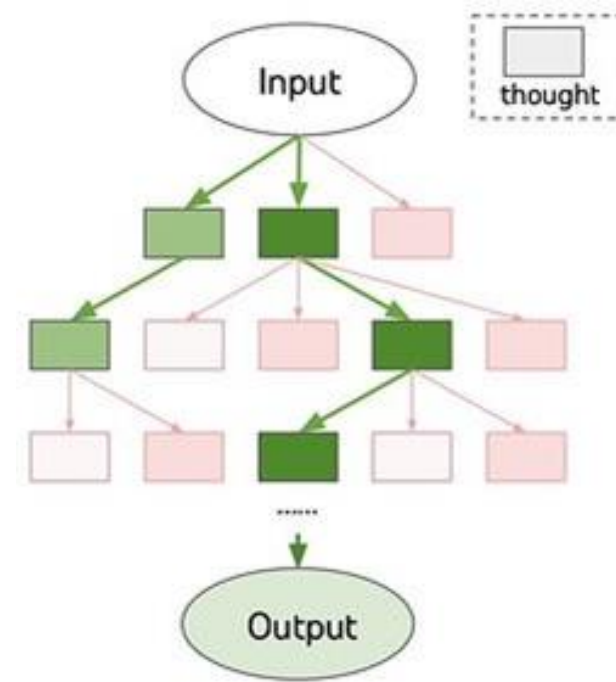


The Chain of Thought Prompting method seeks to improve upon Input Output Prompting by instructing the model to make and display intermediate steps. Instead of just providing input and receiving an output, the model is guided through a problem-solving process, where it outlines its 'thoughts' or steps leading up to the final answer.

Tree of Thought Model

You act as three different experts in primary care medicine discussing this case. Expert A is a PRIMARY CARE PHYSICIAN, Expert B is a NURSE and Expert C is a CLINICIAN. All experts will write down 1 step of their thinking, then share it with the group. Then all experts will go on to the next step, etc. If any expert realises they're wrong at any point then they leave.

The case is: "Chief Complaint: "Fever and back pain." History of Present Illness: "A 78-year-old woman presents to her regular PCP with a 2-day history of fatigue, malaise, and fever. She awoke this morning with a dull ache in her right mid-back and some nausea. She came to the office because she is concerned about the pain and her worsening symptoms. She has been resting and taking acetaminophen (650 mg every 4 to 6 hours), which has helped with the fever and aches, but her symptoms return as the drug wears off. She is unsure of how high her fever has gotten. [...]"



(d) Tree of Thoughts (ToT)

The Tree of Thought Prompting takes a more comprehensive approach to problem-solving by allowing multiple iterations of the Chain of Thought approach. It involves generating multiple 'thoughts' or problem-solving steps for a given prompt and then using the AI model to critique these steps based on their suitability to solve the original problem.

Tree of Thought Model

Expert A (Primary Care Physician)

Step 1: Given the patient's age, presentation, and physical examination findings, my primary differential diagnosis would be a urinary tract infection (UTI). The increased urinary frequency and urgency, combined with the fever and right costovertebral angle tenderness on examination, are suggestive of a possible pyelonephritis (kidney infection). The absence of dysuria (painful urination) does not rule out a UTI, especially in the elderly. I would recommend obtaining a urinalysis and urine culture to confirm the diagnosis.

Expert B (Nurse)

Step 1: From a nursing perspective, I would prioritize ensuring the patient's safety and comfort. Given her concern about living alone and the potential for her condition to worsen, I would recommend arranging for her daughter or another family member to stay with her temporarily. This would provide her with assistance and ensure that she has someone to monitor her symptoms and seek medical attention if needed. Additionally, I would ensure she remains hydrated, as fever and potential UTI can lead to dehydration.

Expert C (Clinician)

Step 1: Considering the patient's presentation and her medication list, it's essential to rule out potential side effects or interactions. Lisinopril/hydrochlorothiazide is an antihypertensive medication that can sometimes lead to electrolyte imbalances. While her symptoms don't directly point to this, it's essential to keep it in mind. I would recommend obtaining basic bloodwork, including a complete blood count (CBC) and basic metabolic panel (BMP), to assess her kidney function, electrolyte levels, and any potential signs of infection.



Action Item	Details	Responsible Expert
Diagnostic Tests	Order a urinalysis with microscopy and a urine culture.	Expert A - PCP
Monitoring Vital Signs	Monitor temperature and blood pressure regularly.	Expert B - Nurse
Hydration & Pain Relief	Ensure patient is adequately hydrated. Provide guidance on OTC pain relief.	Expert B - Nurse
Antibiotic Administration	Once UTI is confirmed, start an appropriate antibiotic regimen considering her age.	Expert A - PCP
Medication Adjustment	Review and adjust Lisinopril/hydrochlorothiazide if necessary.	Expert C - Clinician
Patient Education	Educate on the importance of completing antibiotic course & signs of worsening.	Expert B - Nurse
Home Care	Consider setting up short-term home care or nursing services for daily check-ins.	Expert C - Clinician
Support System Establishment	Involve the patient's nearby daughter in the recovery process.	Expert A - PCP
Follow-Up	Schedule a follow-up appointment after completing the antibiotic	Expert A - PCP

PROFESSIONALS

Action	Expert A (Primary Care Physician)	Expert B (Nurse)	Expert C (Clinician)
Step 1	Obtain urinalysis and urine culture to confirm UTI.	Arrange for a family member to stay with the patient for monitoring and support.	Obtain basic bloodwork (CBC & BMP) to assess kidney function, electrolyte levels, and signs of infection.
Step 2	If UTI is confirmed, prescribe an appropriate antibiotic. Educate the patient on UTI symptoms and when to seek further medical attention.	Educate the patient on the importance of completing the antibiotic course and potential side effects. Provide preventive measures for UTIs.	Schedule a follow-up appointment in a few days to monitor symptoms. Advise the patient to seek medical attention if symptoms worsen or new symptoms develop.
Step 3	If no improvement or worsening symptoms, consider other diagnoses (e.g., kidney stones,	Monitor vital signs regularly. If signs of sepsis develop, send the patient to the emergency	If symptoms are not consistent with UTI or no response to treatment, consider a comprehensive workup. This might

Action Item	Description	Frequency/Duration
Diagnostic Tests		
Urinalysis and urine culture	To confirm urinary tract infection and identify causative organism.	Once at the start of treatment
Medication		
Antibiotics	Prescribe appropriate antibiotics based on urinalysis results and potential organisms (e.g., Ciprofloxacin or Nitrofurantoin).	As recommended (e.g., 7-14 days)
Acetaminophen	For fever and pain management.	As needed
Monitoring & Care		
Vitals monitoring	Track temperature, blood pressure, and other vitals for stability.	Daily, for the first few days
Hydration	Ensure the patient remains hydrated.	Daily
Medication side effect monitoring	Monitor for potential side effects of antibiotics and her regular medications.	Throughout the course of antibiotics
Education & Support		
Signs of complications	Educate on symptoms of worsening conditions such as persistent high fever, chills, or back pain.	Once at the start of treatment

RELATIVES

Action	Expert A (Primary Care Physician)	Expert B (Nurse)	Expert C (Clinician)
Step 1	Obtain urinalysis and urine culture to confirm UTI.	Arrange for a family member to stay with the patient for monitoring and support.	Obtain basic bloodwork (CBC & BMP) to assess kidney function, electrolyte levels, and signs of infection.
Step 2	If UTI is confirmed, prescribe an appropriate antibiotic. Educate the patient on UTI symptoms and when to seek further medical attention.	Educate the patient on the importance of completing the antibiotic course and potential side effects. Provide preventive measures for UTIs.	Schedule a follow-up appointment in a few days to monitor symptoms. Advise the patient to seek medical attention if symptoms worsen or new symptoms develop.
Step 3	If no improvement or worsening symptoms, consider other diagnoses (e.g., kidney stones, diverticulitis).	Monitor vital signs regularly. If signs of sepsis develop, send the patient to the emergency department.	If symptoms are not consistent with UTI or no response to treatment, consider a comprehensive workup. This might include further tests,

Triangle of Care

Information and Knowledge Support:

providing quick access to medical literature, summarizing research, suggesting differential diagnoses based on symptoms, or even reminding about best practices and guidelines.

Administrative Assistance:

assist in administrative tasks such as scheduling, documentation, and even coding, thereby reducing the workload of healthcare professionals and allowing them to focus more on direct patient care.

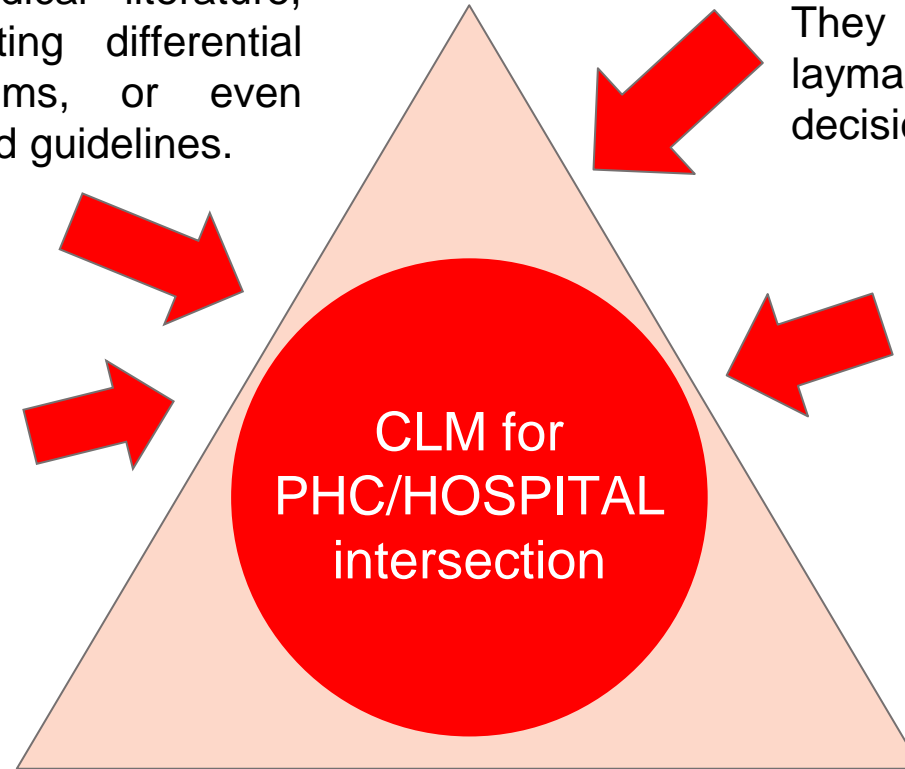
Patient

Facilitating Communication:

intermediaries to gather preliminary patient history, symptoms, or concerns and present them in a structured manner to the physician or nurse. They can help translate medical jargon into layman's terms for patients, aiding in informed decision-making.

Patient Education and Engagement:

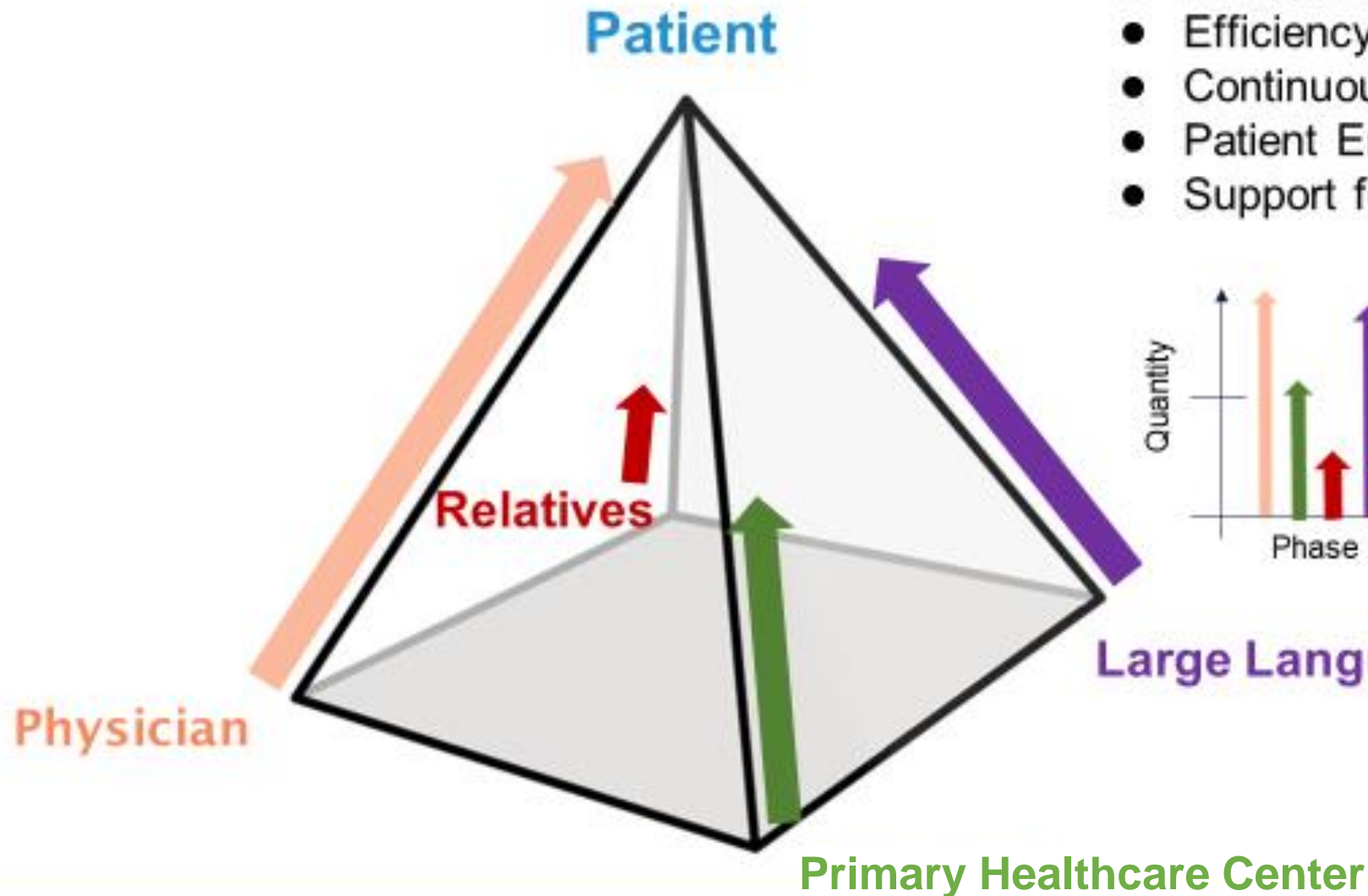
provide patients with understandable explanations of medical conditions, treatments, and procedures. They can answer frequently asked questions, assist in medication adherence, or even offer therapeutic interventions like cognitive behavioral therapy techniques.



Hospital

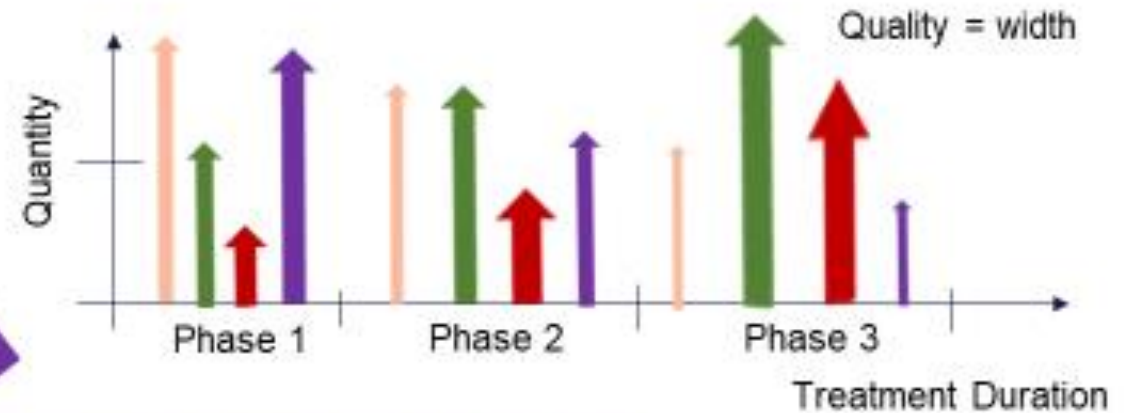
Primary Care Center

“Pyramid of Care” with standardized CLM?



Potential for Multidisciplinary Cooperation

- Holistic Care
- Efficiency and Coordination
- Continuous Learning
- Patient Empowerment
- Support for Care Providers



“Think”-aways

Reliability and Accuracy: CLMs can sometimes provide information that is inaccurate or not up-to-date.

Over-reliance: There's a risk that healthcare professionals might become overly reliant on tools, potentially sidelining their own clinical judgment, experience, and the importance of patient interaction.

Patient Privacy: Using CLMs to discuss patient-specific information might compromise patient confidentiality, especially if the platform isn't compliant with health data protection regulations.

Miscommunication: Relatives might misinterpret or oversimplify the information provided by CLMs leading to confusion, misconceptions, or heightened anxieties about a patient's condition.

Ethical Concerns: The use of AI tools in patient care raises ethical questions. For instance, should a model's suggestion be considered when making end-of-life decisions? How is responsibility shared if an CLM's recommendation leads to an adverse outcome?

Training and Integration: Incorporating CLMs requires training for all stakeholders to use the tool effectively. There could be resistance from older healthcare professionals, or the tool might not integrate seamlessly with existing healthcare IT systems.

Loss of Human Touch: Medicine is not just about diagnosing and treating diseases; it's also about empathy, understanding, and human connection. Over-reliance on digital tools can potentially diminish the human aspect of patient care, which is critical for patient trust and therapeutic relationships.

Sources

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