

# **HeyDocAI**

***Radiology Report Explainer with Evidence-Backed Q&A***

**INFO 7375 - Prompt Engineering for Generative AI  
Generative AI Project - Final Report**

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## 1. Introduction

Radiology reports are critical medical documents but are often written in highly technical language that is difficult for patients and non-medical users to understand. Misinterpretation can lead to anxiety, misinformation, or incorrect assumptions about health conditions.

HeyDocAI is a Generative AI system designed to bridge this gap by:

- Translating radiology reports into plain English
- Extracting structured clinical information
- Answering user questions using evidence-backed retrieval

The system leverages **Retrieval-Augmented Generation (RAG)** and **Prompt Engineering** to ensure accuracy, transparency, and reliability.

This system is intended for **educational purposes only** and does not provide medical diagnosis or treatment advice.

## 2. Objectives

The primary objectives of this project are:

1. Build a real-world Generative AI application in the healthcare domain
2. Implement **Retrieval-Augmented Generation (RAG)** using a vector database
3. Design robust **prompt engineering workflows**
4. Provide evidence-backed answers with citations
5. Evaluate system performance using quantitative metrics

## 3. Core Generative AI Components Used

This project implements **two required components**:

### 3.1 Prompt Engineering

- System-level instructions defining assistant behavior
- Task-specific prompts:
  - Explanation (Simple / Normal / Clinician)
  - Structured extraction (JSON)
  - Evidence-based Q&A
- Context injection with retrieved evidence
- Guardrails for edge cases and hallucination prevention

### 3.2 Retrieval-Augmented Generation (RAG)

- Domain-specific knowledge base (radiology PDFs)
- Vector storage using Pinecone
- Semantic retrieval using OpenAI embeddings
- Evidence ranking and filtering before generation
- Citation formatting with source and page numbers

## 4. System Architecture

The system follows modular, evidence-first architecture.

### Architecture Flow

- User inputs a radiology report or question via Streamlit UI
- Input is validated using guardrails
- RAG orchestration retrieves relevant evidence from Pinecone
- Evidence + context injected into prompts
- OpenAI LLM generates grounded responses
- Citations are displayed alongside answers

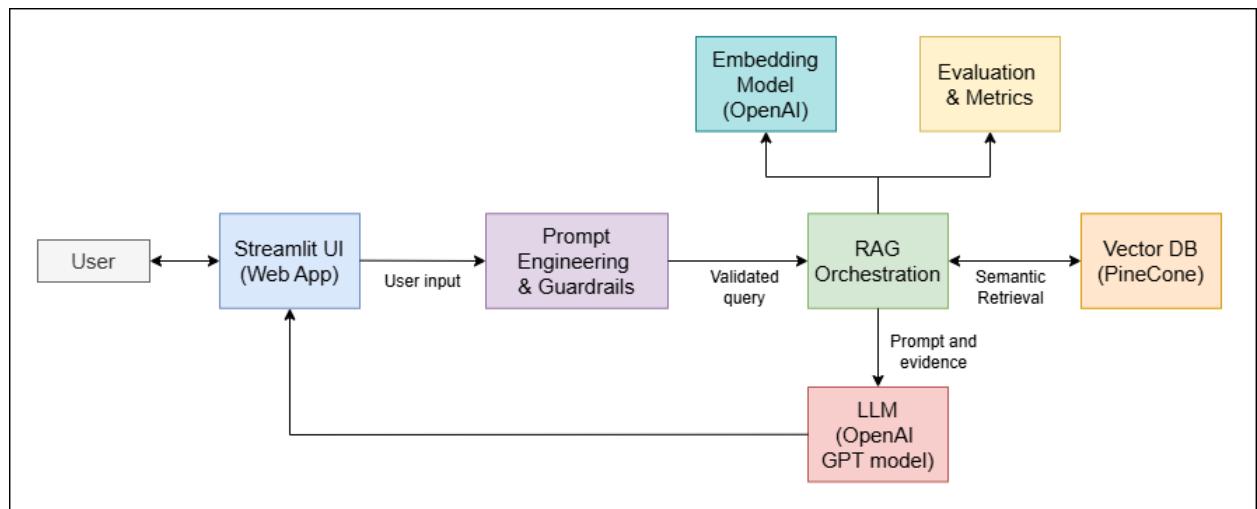


Figure 1. System Architecture Diagram

## 5. Knowledge Base Construction

The knowledge base consists of curated, authoritative radiology reference PDFs, including:

- Chest X-ray interpretation guides
- Thoracic imaging glossaries
- Lung pathology references (effusion, consolidation, pneumothorax)

### Processing Steps

- PDF text extraction
- Page-level chunking
- Overlapping chunk strategy
- Embedding generation using OpenAI
- Storage in Pinecone vector database

This enables precise semantic retrieval for downstream generation.

The screenshot shows the HeyDocAI web application running locally at `localhost:8501`. The interface includes a navigation bar with icons for search, star, user, and more, along with a 'Deploy' button. The main header features the 'heyDoc' logo and the text 'HeyDocAI'. Below the header, a sub-header reads 'Confused by radiology jargon? HeyDocAI is here to explain!'. A note states 'Only explanations with citations. Not medical advice.' The main content area is divided into two sections: 'Input Radiology Report' on the left and 'Explain the report' on the right. The 'Input Radiology Report' section contains a text input field with placeholder 'Paste a radiology report here:', a 'Load Sample Report' button, and a 'Reset' button. The 'Explain the report' section includes tabs for 'Explain' (which is selected), 'Extract', and 'Evidence Q&A'. It features an 'Explanation level' dropdown set to 'normal' with a 'Generate Explanation' button below it. A yellow callout box at the bottom left of this section says 'Please provide a radiology report to analyze.' At the bottom of the page is a footer with a link to 'Advanced: Retrieval Settings (Pinecone)'.

## 6. Application Features

### 6.1 Explain Radiology Reports

- Converts reports into plain-English explanations
- Supports three explanation levels:
  - Simple (patient-friendly)
  - Normal
  - Clinician-oriented
- Displays retrieval statistics and citations

The screenshot shows the HeyDocAI web application. At the top, there's a logo with a blue 'D' and the text 'HeyDocAI'. Below it, a message says 'Confused by radiology jargon? HeyDocAI is here to explain!'. A note below states 'Only explanations with citations. Not medical advice.' The main area is divided into two sections: 'Input Radiology Report' on the left and 'Explain the report' on the right.

**Input Radiology Report:** This section contains a text input field with a sample report about a Chest X-ray. The report includes clinical history ('Shortness of breath'), findings ('Mild patchy opacity in the right lower lung, No pleural effusion, No pneumothorax. Cardiomedastinal silhouette is within normal limits.'), and an impression ('Mild right lower lobe opacity may represent atelectasis versus early infection. Correlate clinically.'). Buttons for 'Load Sample Report' and 'Reset' are present.

**Explain the report:** This section has a dropdown menu for 'Explanation level' set to 'normal'. A button 'Generate Explanation' is visible. A green progress bar indicates 'Done in 9.69s'. Below the bar, a message says 'Run stats: 5 chunks used | top score 0.661'.

**Explanation in Plain English:** This section displays the generated explanation. It starts with a 'Summary:' heading and a bulleted list: 'The chest X-ray shows mild patchy opacity in the right lower lung.', 'There is no fluid buildup (pleural effusion) or air leak (pneumothorax).', and 'The heart and surrounding structures appear normal in size and shape.' A note below says 'Key terms explained:'.

### 6.2 Structured Information Extraction

- Extracts findings, impressions, and key entities
- Outputs JSON and structured tables
- Useful for downstream clinical workflows

This screenshot shows the HeyDocAI interface for extracting structured information. The layout is similar to the previous one, with 'Input Radiology Report' on the left and 'Extract structured information (JSON)' on the right.

**Input Radiology Report:** The same sample Chest X-ray report is shown here.

**Extract structured information (JSON):** This section features a button 'Extract Fields'. A green progress bar indicates 'Done in 3.50s'. Below it, a note says 'Model did not return valid JSON. Showing raw output:'. The raw JSON output is displayed as follows:

```
[{"modality": "CHEST X-RAY (PA AND LATERAL)", "body_part": "chest", "findings": ["Mild patchy opacity in the right lower lung", "No pleural effusion", "No pneumothorax", "Cardiomedastinal silhouette is within normal limits"], "impression": ["Mild right lower lobe opacity may represent atelectasis versus early infection", "Correlate clinically"], "key_terms": ["opacity", "atelectasis", "infection", "pleural effusion", "pneumothorax"], "uncertainty_phrases": [], "critical_flags": [], "recommended_followup_in_report": ["Correlate clinically"]}]
```

**Important:** I am not a doctor and this is not medical advice. I can help explain radiology language and summarize the text, but you should consult a qualified clinician for diagnosis or treatment.

### 6.3 Evidence-Backed Q&A

- Users ask questions about the report
- Answers generated only if sufficient evidence is retrieved
- All responses include citations
- Chat history maintained for context

The screenshot shows the HeyDocAI web application. At the top, there's a logo with 'hey' and 'Doc' and the text 'HeyDocAI'. Below it, a subtext says 'Confused by radiology jargon? HeyDocAI is here to explain!'. A note below that says 'Only explanations with citations. Not medical advice.' The main area has tabs: 'Explain', 'Extract', and 'Evidence Q&A' (which is underlined in red). On the left, there's a section titled 'Input Radiology Report' with a text input field containing a sample radiology report. This report includes findings from a chest X-ray and an impression. Buttons for 'Load Sample Report' and 'Reset' are below the input field. To the right, under 'Ask questions (answers must cite sources)', there are three buttons: 'Explain the impression', 'Is anything urgent?', and 'Define key terms'. Below these buttons is a callout box with a magnifying glass icon and the text 'Define key terms mentioned in this report (e.g., opacity, atelectasis, effusion.)'. Another callout box below it has a book icon and the text 'Key Terms Defined:' followed by a bulleted list explaining three medical terms: Opacity, Atelectasis, and Effusion.

## 7. Guardrails and Safety Measures

To ensure reliability and ethical use, the system implements:

- Empty / invalid input validation
- Minimum similarity score thresholds
- “I don’t know” responses when evidence is insufficient
- Mandatory medical disclaimers
- Citation enforcement for generated answers

These measures significantly reduce hallucination risk.

## 8. Performance Evaluation

Automated evaluation was conducted using a standardized query set.

### Metrics Measured

- Average response latency
- Evidence availability rate

- Citation coverage
- Citation coverage when evidence is available

## Results Summary

- Average latency: ~4–5 seconds
- Evidence availability: ~90%
- Citation coverage (given evidence): **100%**

### Snipped of eval/results.json:

```

"id": "q1_ggo_definition",
"type": "definition",
"question": "What does ground-glass opacity mean in a radiology report?",
"latency_sec": 12.714,
"retrieved_chunks_count": 5,
"citations_present": true,
"citations_ui": [
    "[1] thoracic_imaging_glossary_fleischner.pdf \u2014 page 35 (score: 0.600)",
    "[2] thoracic_imaging_glossary_fleischner.pdf \u2014 page 6 (score: 0.592)",
    "[3] thoracic_imaging_glossary_fleischner.pdf \u2014 page 9 (score: 0.576)",
    "[4] thoracic_imaging_glossary_fleischner.pdf \u2014 page 19 (score: 0.575)",
    "[5] thoracic_imaging_glossary_fleischner.pdf \u2014 page 47 (score: 0.560)"
],
"top_sources": [
{
    "source": "thoracic_imaging_glossary_fleischner.pdf",
    "page": 35,
    "score": 0.6001
},
{
    "source": "thoracic_imaging_glossary_fleischner.pdf",
    "page": 6,
    "score": 0.5917
}
]

```

## 9. Challenges and Solutions

### Challenge 1: Hallucinated Medical Responses

Solution: Strict evidence validation and refusal to answer without sufficient retrieval.

### Challenge 2: Overly Technical Explanations

Solution: Multi-level prompt templates tailored to user expertise.

### Challenge 3: Long, Complex Radiology Documents

Solution: Chunking + overlap strategy with ranking and filtering.

## 10. Ethical Considerations

- No personal health data is stored
- No diagnosis or treatment recommendations
- Transparent citation of sources
- Bias minimized by grounding answers in trusted references
- Clear disclaimers shown in UI

## 11. Future Improvements

- Multimodal support (X-ray images + text)
- Expanded medical domains (CT, MRI, ultrasound)
- Improved ranking strategies (MMR, re-ranking models)
- Cloud deployment with authentication
- Multilingual support

## 12. Conclusion

**HeyDocAI** demonstrates how Generative AI can be safely and effectively applied in healthcare education. By combining **Prompt Engineering** with **Retrieval-Augmented Generation (RAG)**, the system delivers transparent, reliable, and user-friendly explanations of complex medical documents.

This project showcases a practical, real-world application of modern Generative AI techniques while addressing ethical and reliability concerns.

## 13. Appendix

- GitHub: <https://github.com/Ranjithnathk/HeyDoc-AI-RAG-Medical-Report-Explainer>
- Screenshots: docs/screens/
- Evaluation Results: eval/results.json
- Video Demonstration