Introducing Natural Language Processing in Cardiology

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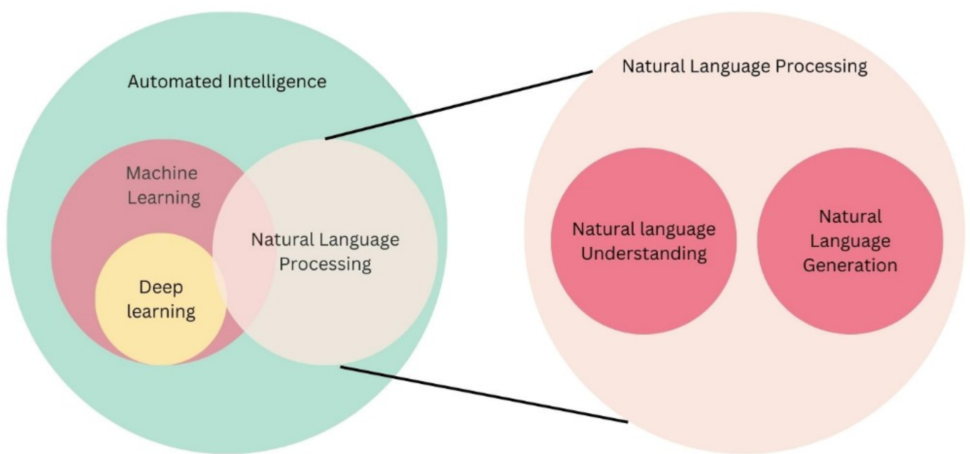
Take Home Messages

- Natural Language Processing (NLP) is a powerful tool that enables computers to understand and work with human language in healthcare.
- In cardiology, NLP has demonstrated its potential in Electronic Health Records analysis, cardiac imaging, and patient communication.
- NLP's uses and limitations in healthcare are still under exploration due to Ethical challenges posed by the technology.

Since Alan Turing posed the question "Can Machines Think?" and introduced the Turing Test for Artificial Intelligence in 1950(1), significant progress has been made in the field of Artificial Intelligence, and several fields of AI are now being used in healthcare. We venture into the realm of Natural Language Processing (NLP), a multi-disciplinary field that combines linguistics, computer science, and artificial intelligence. This innovative technology enables machines to not only comprehend and interpret human language but also communicate effectively, imparting clarity and context to the vast expanse of healthcare data(2). In this article, we delve into the history, utilisation, and obstacles of NLP in healthcare, revealing its role in improving patient care and reshaping the future of medicine.

The Basics of Natural Language Processing (NLP)

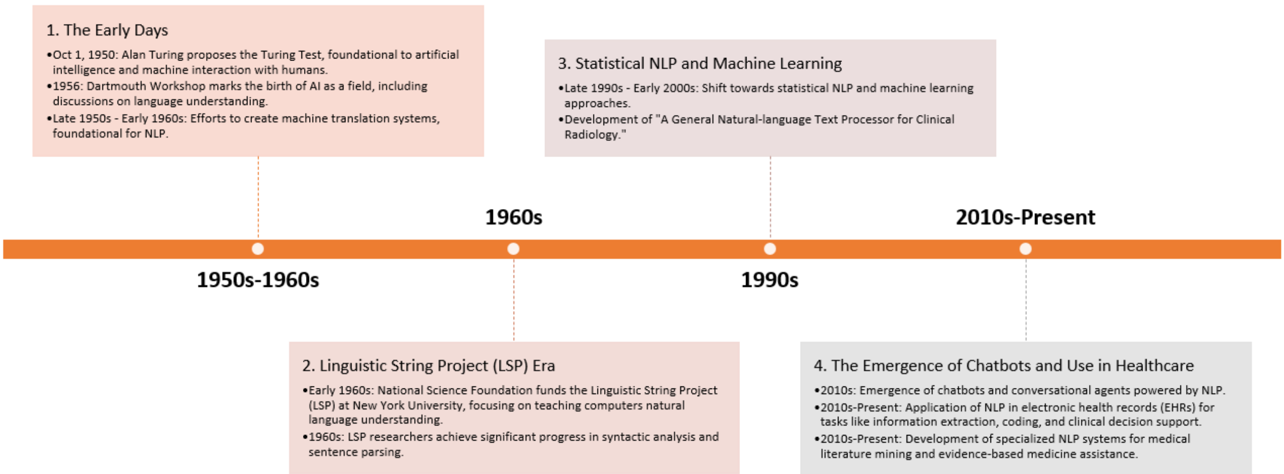
NLP is the art of teaching computers how humans commincate(3). NLP includes Natural Language Understanding (NLU) for sentence analysis and semantics, and Natural Language Generation (NLG) for text generation and summarisation.



Timeline of Development of Natural Language Processing

Period	Milestones and Developments
The Early Days (1950s-1960s)	- Alan Turing proposes the Turing Test, foundational to artificial intelligence and machine interaction with humans(1 Oct 1950) (1) - In 1956, the Dartmouth Workshop marks the birth of artificial intelligence (AI) as a field and includes discussions on language understanding (4). - In the late 1950s and early 1960s, efforts are made to create machine translation systems that lay the foundation for NLP.
Linguistic String Project (LSP) Era (1960s)	- In the early 1960s, the National Science Foundation funds the Linguistic String Project (LSP) at New York University, aiming to teach computers how to understand natural language(5–7). - LSP researchers make significant progress in the development of techniques for syntactic analysis and sentence parsing(8).
Statistical NLP and Machine Learning (1990s-Present)	- In the late 1990s and early 2000s, a shift towards statistical NLP and machine learning approaches occurs(9). - A General Natural-language Text Processor for Clinical Radiology(10)
The Emergence of Chatbots and use in healthcare (2010s-Present)	- The 2010s mark the emergence of chatbots and conversational agents powered by NLP. - NLP is applied to electronic health records (EHRs) for tasks such as information extraction, coding, and clinical decision support (11,12). - Specialized NLP systems for medical literature mining and evidence-based medicine assistance are developed (13)

Table 1 and Timeline below provide overview of NLP Historical Milestones.



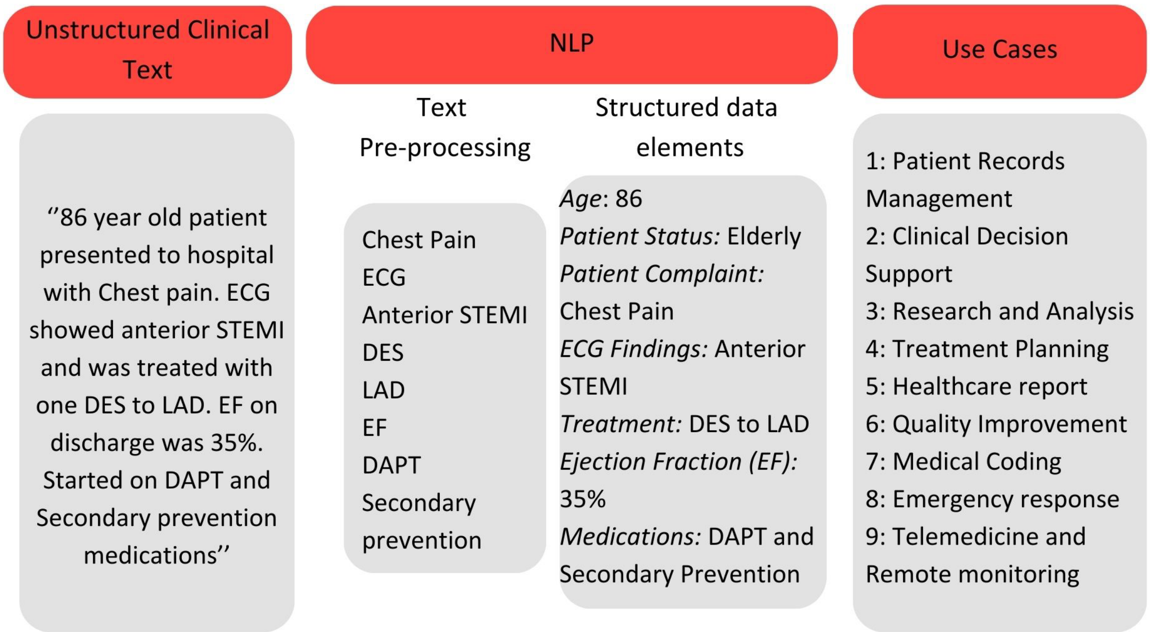


Figure 2 Illustrates the application of natural language processing (NLP) in extracting and interpreting responses from a unstructured medical narrative.

Current and Future Applications of NLP in Cardiology.

Cardiology is rapidly adopting digital technologies, from sophisticated diagnostic tools to electronic monitoring, creating an abundance of data. Natural Language Processing (NLP) offers innovative ways to analyse this data, both in current applications and potential future advancements. Some of them are discussed below.

Electronic Health Records - NLP's application in Electronic Health Records (EHRs) unlocks new research areas by leveraging the vast data from healthcare systems(2,14–16). NLP can uncover subtle details buried within clinical narratives, offering a deeper understanding of patients' conditions (17). Common uses include disease coding, clinical note analysis, and named entity recognition(2).

Imaging- NLP is particularly beneficial in interpreting echocardiography reports, extracting key data elements, and generating concise summaries(18). It accelerates and maintains consistency in report summarisation(19).

Voice assistants and chatbots- NLP enables the development of interactive patient interfaces like chatbots and voice assistants, enhancing engagement through conversational access to information and aiding in remote monitoring and education. It's notably useful in pre-diagnosis for symptom-based patient categorization (20).

Heart failure NLP identifies patients at risk of developing heart failure by analyzing EHRs for symptoms, medical history, and medications(21,22). This includes extracting critical information like shortness of breath, swelling, fatigue, and history of conditions like diabetes and hypertension. Furthermore, NLP has been instrumental in refining disease identification, classification, and predicting patient outcomes such as readmissions and mortality. The incorporation of NLP into the management of heart failure provides a more intricate comprehension of patients' conditions and assists in customizing individualized treatment strategies. However, additional research is required to validate its effectiveness in conjunction with echocardiography.(17,23,24).

Coronary artery disease*:* In CAD research, NLP algorithm surpassed conventional risk scores(GRACE and TIMI scores), achieving a 72% AUC for predicting major adverse cardiovascular events. Another algorithm, also with a 72% AUC, identified factors influencing admission risk after cardiac catheterization, such as age, gender, and medical history.(18).

Electrophysiology: In electrophysiology, advances include the development of algorithms for identifying atrial fibrillation (AF) in patients with cardiac implantable electronic devices (CIEDs) and evaluating thromboembolic prophylaxis. These studies utilized natural language processing (NLP) to extract patient data from electronic health records (EHRs) and calculate CHA2DS2-VASc scores, achieving high accuracy.

ACHD*:* NLP holds promise in extending its utility to the identification and prediction of events related to congenital heart diseases. Through the extraction of information from EHRs, NLP may assist in identifying patients with ACHD and assessing their risk of developing complications, potentially informing tailored monitoring and intervention strategies.

Inherited cardiomyopathy*:* NLP could identify patients at risk of events related to inherited cardiomyopathies by analyzing family histories, genetic testing results, and imaging findings in EHRs.

Sports cardiology and Maternal/Fetal cardiovascular medicine*:* Within sports cardiology and maternal/fetal cardiovascular medicine, NLP has the potential to aid in the identification of athletes at risk of cardiovascular issues and the prediction of cardiovascular events in pregnant women and foetuses.

Ethical Concerns in Healthcare NLP

The rapid advancement of NLP holds immense promise for the enhancement of patient care, diagnostics, and treatment modalities in healthcare. However, this progress simultaneously ushers in significant ethical considerations. These encompass critical aspects such as safeguarding patient data privacy, mitigating algorithmic bias, ensuring transparency in AI-driven decision-making processes, and adhering to stringent healthcare regulations, as highlighted by the Topol reprot. As NLP continues its integration into healthcare systems, it becomes increasingly vital to tackle these ethical challenges in a responsible manner. Central concerns include the secure management of patient data, the promotion of fairness and transparency in AI systems, the preservation of healthcare professionals' autonomy, the pursuit of accessibility and equitable healthcare solutions, the establishment of accountability frameworks for AI-driven decisions(25).

Conclusion:

- NLP has evolved significantly from its inception, has a potential to revolutionize the healthcare industry through Its ability to extract valuable insights from Electronic Health Records, aid in medical imaging interpretation, and facilitate patient communication.
- With ongoing advancements, NLP is set to further enhance healthcare delivery, making it more personalized and efficient.
- There are significant Ethical challenges which will limit the open use of this technology, more needs to be done to address ethical concerns posed by NLP and AI in general.

Disclosure

None

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