Atención Primaria

ORIGINAL ARTICLE

Artificial intelligence and natural language processing for improved telemedicine: Before, during and after remote consultation

Tiago Cunha Reis

Universidade de Lisboa, Faculdade de Medicina, Avenida Professor Egas Moniz, 1649-028 Lisboa, Portugal

Abstract The rapid evolution of telemedicine has revealed significant documentation and workflow challenges. Clinicians often struggle with the administrative burdens of telehealth visits, sacrificing valuable time better spent in direct patient interaction. This issue is further compounded by the need to maintain accurate and comprehensive records, which can be time-consuming and prone to error when approached manually. In this context, integrating artificial intelligence (AI) and natural language processing (NLP) technologies presents a transformative opportunity. Automating documentation and enhancing workflow efficiency can revolutionize healthcare delivery, alleviating clinician workloads and improving clinical quality and patient safety. Therefore, examining the application of these cutting-edge technologies becomes imperative in addressing the pressing needs of modern healthcare and optimizing health outcomes. The significance of integrating AI and NLP technologies in clinical remote practice cannot be overstated. Hence, this article aims to inspire and motivate healthcare professionals to embrace these transformative changes.

Inteligencia artificial y procesamiento de lenguaje natural para mejorar la telemedicina: antes, durante y después de la consulta remota

Resumen La rápida evolución de la telemedicina ha revelado importantes desafíos en la documentación y el flujo de trabajo. Los clínicos a menudo enfrentan dificultades con las cargas administrativas de las consultas por telemedicina, sacrificando un tiempo valioso que podría destinarse a la interacción directa con los pacientes. Este problema se agrava aún más por la

E-mail address: reis.tiago@edu.ulisboa.pt

necesidad de mantener registros precisos y completos, lo que puede ser un proceso que consume mucho tiempo y es propenso a errores cuando se realiza manualmente. En este contexto, la integración de tecnologías de inteligencia artificial (IA) y procesamiento de lenguaje natural (PLN) presenta una oportunidad transformadora. La automatización de la documentación y la mejora de la eficiencia en el flujo de trabajo pueden revolucionar la prestación de servicios de salud, aliviando la carga de trabajo de los clínicos y mejorando la calidad clínica y la seguridad del paciente. Por lo tanto, resulta imperativo examinar la aplicación de estas tecnologías de vanguardia para abordar las necesidades urgentes de la atención médica moderna y optimizar los resultados de salud. La importancia de integrar tecnologías de IA y PLN en la práctica clínica remota no puede ser subestimada. Por ende, este artículo tiene como objetivo inspirar y motivar a los profesionales de la salud a adoptar estos cambios transformadores.

Overview of telemedicine workflow: growing importance and implications

The integration of telemedicine into healthcare systems has fundamentally altered the dynamics of patient-provider interactions, enhancing access to care while addressing the pressing challenges posed by traditional in-person visits. As healthcare evolves, the need for innovative solutions to improve efficiency and patient engagement has propelled telemedicine to the forefront of medical practice, especially amid the COVID-19 pandemic, which underscored the critical utility of remote healthcare delivery mechanisms. Notably, telemedicine has demonstrated its potential to bridge gaps in accessibility and equity in healthcare, catering to rural and underserved populations who traditionally face barriers to care. Furthermore, the advent of AI and NLP technologies promises to optimize telemedicine workflows, reduce documentation burdens, streamline clinical processes, and enhance patient care quality and safety. These advancements underscore the urgent need for an adaptive healthcare framework seamlessly integrating telemedicine with cutting-edge technologies. The urgency of this integration cannot be overstated, as it is crucial for meeting the diverse needs of patients and providers alike and ensuring the future of healthcare.

Despite telemedicine offering unprecedented opportunities for patient care, it also presents significant challenges related to documentation and workflow efficiency. Healthcare providers often find themselves burdened by the time-consuming nature of manual documentation, detracting from direct patient interaction and adversely affecting clinical outcomes. Moreover, the variability in reporting standards and documentation requirements can lead to inconsistencies and errors that compromise patient safety and care continuity. Studies indicate that the majority of healthcare professionals acknowledge gaps in their digital skills, exacerbated by the rapid transition to telehealth during the COVID-19 pandemic.[1] Technological disparities, particularly among underserved populations, threaten equitable access to telemedicine and create additional documentation hurdles. In this context, integrating AI and NLP technologies emerges as a potential remedy, capable of automating and streamlining documentation processes. However, adopting these innovative tools hinges on addressing the existing ethical considerations and ensuring systematic training for all stakeholders involved in telehealth services.

AI and NLP as transformative technologies: before, during, and after remote consultation

AI refers to developing computer systems capable of performing tasks that typically require human intelligence, such as learning, reasoning, and problem-solving. In healthcare, AI algorithms can rapidly analyze vast amounts of patient data, uncovering patterns and generating insights that might not be immediately apparent to human clinicians. Nonetheless, NLP is a subset of AI focused on the interaction between computers and human language. It enables the interpretation and analysis of unstructured text data, such as clinical notes and electronic health records (EHRs), allowing for the seamless extraction of relevant clinical information. By automating the processing of this information, NLP facilitates more efficient documentation and enhances the accuracy of patient records. These advancements in AI and NLP expedite routine tasks and significantly reduce clinician burnout by minimizing the administrative burden associated with telemedicine documentation. However, successfully integrating these technologies into healthcare systems requires addressing challenges such as data privacy concerns and comprehensive training to ensure these tools are accessible and effective across diverse patient populations. Ultimately, AI and NLP are poised to be powerful catalysts for innovation in telehealth, driving improvements in care delivery and operational workflows, particularly within Family Medicine and General Practice.

AI before consultation

Before a remote consultation, AI and NLP algorithms can analyze patient data, uncover patterns, and generate insights that may elude human clinicians (Fig. 1), briefing patient information and status. As an example, Feller
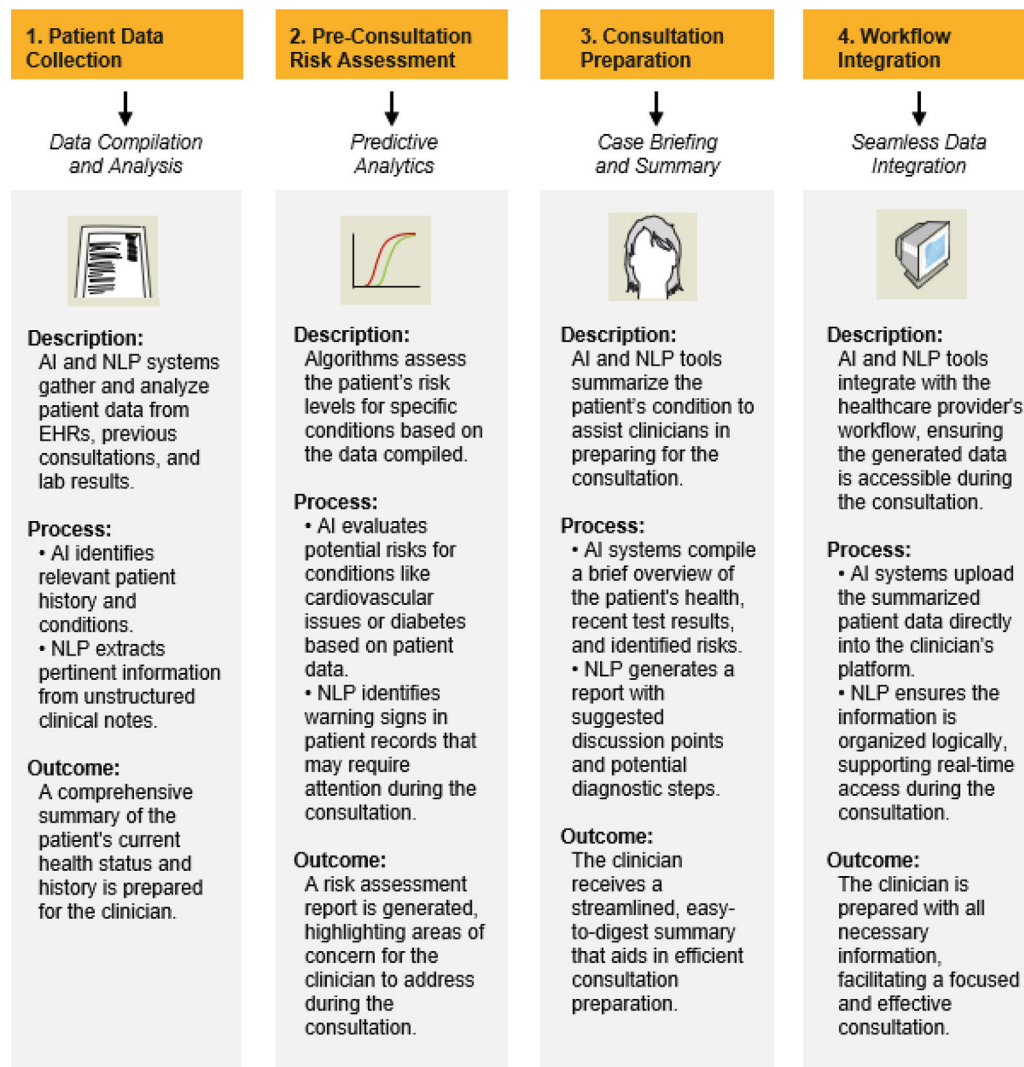
1. Patient Data Collection	2. Pre-Consultation Risk Assessment	3. Consultation Preparation	4. Workflow Integration
↓	↓	↓	↓
Data Compilation and Analysis	*Predictive Analytics*	*Case Briefing and Summary*	*Seamless Data Integration*
Description: AI and NLP systems gather and analyze patient data from EHRs, previous consultations, and lab results.	**Description:** Algorithms assess the patient's risk levels for specific conditions based on the data compiled.	**Description:** AI and NLP tools summarize the patient's condition to assist clinicians in preparing for the consultation.	**Description:** AI and NLP tools integrate with the healthcare provider's workflow, ensuring the generated data is accessible during the consultation.
Process: • AI identifies relevant patient history and conditions. • NLP extracts pertinent information from unstructured clinical notes.	**Process:** • AI evaluates potential risks for conditions like cardiovascular issues or diabetes based on patient data. • NLP identifies warning signs in patient records that may require attention during the consultation.	**Process:** • AI systems compile a brief overview of the patient's health, recent test results, and identified risks. • NLP generates a report with suggested discussion points and potential diagnostic steps.	**Process:** • AI systems upload the summarized patient data directly into the clinician's platform. • NLP ensures the information is organized logically, supporting real-time access during the consultation.
Outcome: A comprehensive summary of the patient's current health status and history is prepared for the clinician.	**Outcome:** A risk assessment report is generated, highlighting areas of concern for the clinician to address during the consultation.	**Outcome:** The clinician receives a streamlined, easy-to-digest summary that aids in efficient consultation preparation.	**Outcome:** The clinician is prepared with all necessary information, facilitating a focused and effective consultation.

Figure 1   Pre-consultation workflow integration of AI and NLP in telemedicine.

et al.[2] successfully developed a model to automate HIV risk assessment using the patients' EHRs, employing keyword identification, variable selection, and statistical modeling with proper classifiers. From already existent unstructured textual information, Carson et al.[3] developed a tool that detects suicide risk in adolescents, requiring no pre-processing by clinicians. NLP models have also been employed to pre-assess conditions of risk, such as for lupus nephritis,[4] perinatal self-harm,[5] or delirium.[6] In addition to the patient's briefing, such technologies have demonstrated substantial reductions in documentation reading time across several specialties, allowing clinicians to focus more on preparing consultations. Namely, in the case of cancer staging, Warner et al.[7] demonstrated that such automated methods contribute to fast and accurate information extraction from narrative EHRs. Moreover, the authors reported that the stage can be automatically captured in a shorter timeframe than the 6-month window used by cancer registries, as early as 5 weeks from diagnosis. Leyh-Bannurah et al.[8] developed an automated solution to extract detailed information from narrative EHRs in Urology, where their approach allows the NLP pipeline to be generalized to other genitourinary EHRs and tumor entities. On the other hand, Yang et al.[9] developed an open-sourced large clinical language model capable of performing five pre-consultation clinical NLP tasks, including clinical concept extraction, medical relation extraction, semantic textual similarity, natural language inference, and medical question answering, significantly reducing preparation time for before consultation. By leveraging AI and NLP technologies prior to remote consultations, healthcare providers can enhance the preparation process, leading to more informed and effective patient interactions. This proactive approach lays the foundation for improved diagnostic accuracy and personalized care during the consultation.

AI during consultation

Due to time constraints and difficulty accurately assessing nonverbal cues in a virtual format, remote patient consultation is often associated with truncated
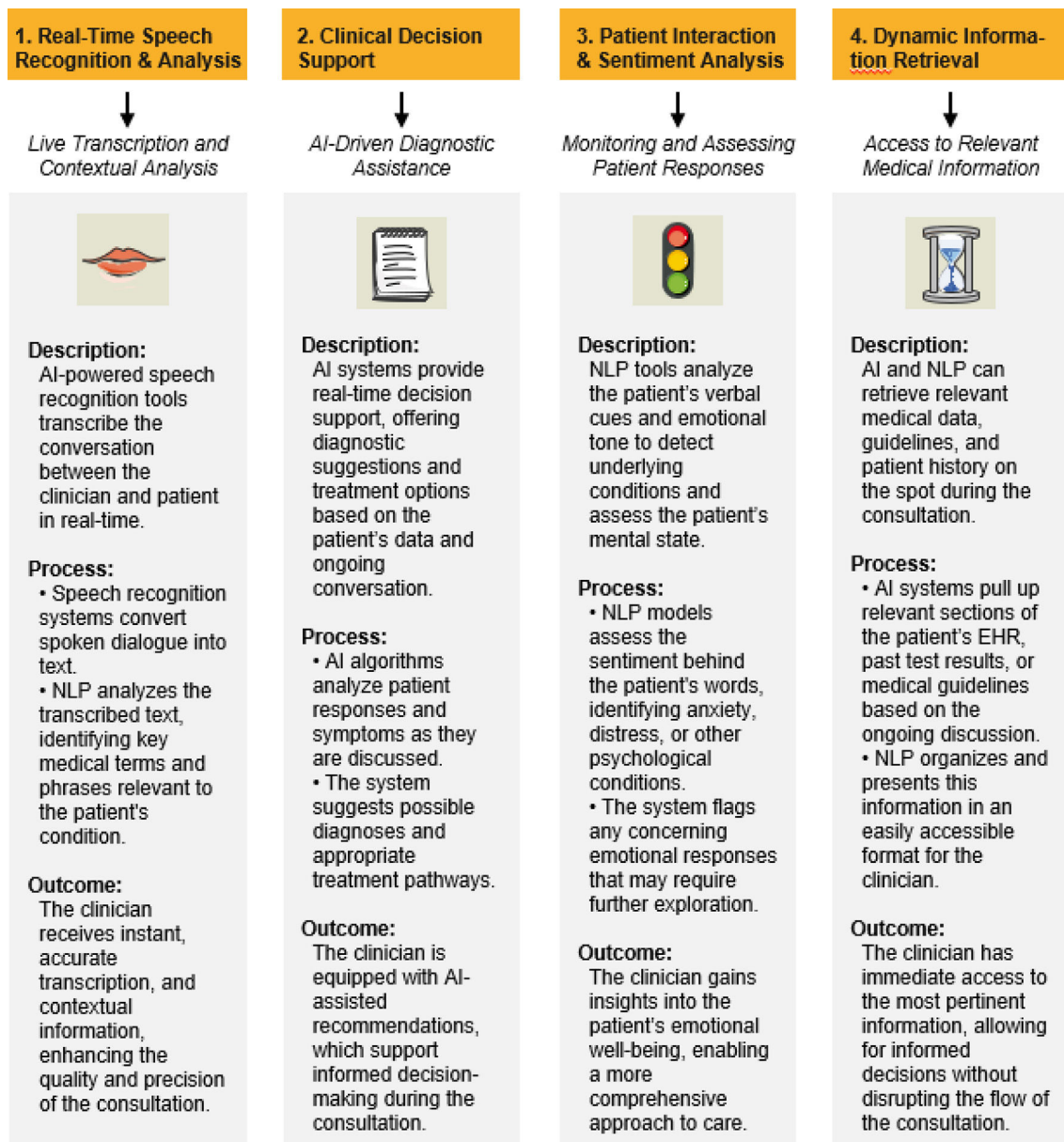
1. Real-Time Speech Recognition & Analysis	2. Clinical Decision Support	3. Patient Interaction & Sentiment Analysis	4. Dynamic Information Retrieval
Live Transcription and Contextual Analysis	*AI-Driven Diagnostic Assistance*	*Monitoring and Assessing Patient Responses*	*Access to Relevant Medical Information*
Description: AI-powered speech recognition tools transcribe the conversation between the clinician and patient in real-time.	**Description:** AI systems provide real-time decision support, offering diagnostic suggestions and treatment options based on the patient's data and ongoing conversation.	**Description:** NLP tools analyze the patient's verbal cues and emotional tone to detect underlying conditions and assess the patient's mental state.	**Description:** AI and NLP can retrieve relevant medical data, guidelines, and patient history on the spot during the consultation.
Process: • Speech recognition systems convert spoken dialogue into text. • NLP analyzes the transcribed text, identifying key medical terms and phrases relevant to the patient's condition.	**Process:** • AI algorithms analyze patient responses and symptoms as they are discussed. • The system suggests possible diagnoses and appropriate treatment pathways.	**Process:** • NLP models assess the sentiment behind the patient's words, identifying anxiety, distress, or other psychological conditions. • The system flags any concerning emotional responses that may require further exploration.	**Process:** • AI systems pull up relevant sections of the patient's EHR, past test results, or medical guidelines based on the ongoing discussion. • NLP organizes and presents this information in an easily accessible format for the clinician.
Outcome: The clinician receives instant, accurate transcription, and contextual information, enhancing the quality and precision of the consultation.	**Outcome:** The clinician is equipped with AI-assisted recommendations, which support informed decision-making during the consultation.	**Outcome:** The clinician gains insights into the patient's emotional well-being, enabling a more comprehensive approach to care.	**Outcome:** The clinician has immediate access to the most pertinent information, allowing for informed decisions without disrupting the flow of the consultation.

Figure 2   AI and NLP integration during remote consultation in telemedicine.

communication. In this way, AI and NLP approaches can also reshape doctor–patient consultations (Fig. 2). For instance, innovative tools enable real-time analysis of patient dialogue, facilitating the extraction of critical medical information pertinent to diagnosis and treatment. This integration enhances diagnostic accuracy and communication, as NLP allows for seamless transcription and enhances post-note writing quality. By incorporating advanced algorithms, AI and NLP facilitate real-time dialogue analysis, allowing medical professionals to effectively extract pertinent information from patient visual and behavioral interactions. For example, Micek et al.[10] conclude that introducing a remote scribe program significantly reduced physicians' burnout since it contributes to overall professional wellness. As observed, AI and NLP methodologies not only streamline the physician's workflow by reducing the cognitive load associated with processing verbal information but also enhance the overall accuracy of medical assessments. By automating routine tasks such as note-taking and data entry, these technologies diminish the administrative burdens contributing to clinician fatigue. Moreover, as consultations unfold, these technologies can identify keywords and phrases indicative of specific clinical conditions or concerns, significantly enhancing the depth of information gathered during the encounter. NLP-based approaches can discern patient sentiments and cues that may suggest underlying psychological issues, prompting physicians to address these aspects in a better, more supportive, and clinically comprehensive way. Furthermore, by integrating real-time collected clinical data and guidelines into their analyses, such AI systems can provide decision support, highlighting best practices or suggested

treatment pathways based on the synthesized information from the dialogue. Recently, Costa et al.[11] reported an AI model to transcribe, extract, and classify unstructured emergency call data, which achieved notable accuracy despite the challenges of language and context. Thus, such AI-centric functionalities contribute to a more efficient, responsive, and content-rich consultation, ultimately prioritizing patient-centered care. Integrating AI and NLP during remote consultations enables real-time data analysis and decision support, ensuring clinicians can provide accurate and timely care while reducing the cognitive load. This seamless integration is crucial for maintaining high standards of patient-centered care in a virtual setting.

AI after consultation

The integration of AI and NLP in telemedicine extends beyond the point of remote consultations, playing a crucial role in enhancing the quality of care provided after the patient and clinician have concluded their virtual interaction (Fig. 3). Today, AI-centric technologies offer transformative potential in automating documentation, streamlining workflows, enhancing diagnostic accuracy, and improving patient outcomes. One of the most immediate benefits of AI and NLP following a remote consultation is the automation of documentation processes. Traditionally, healthcare providers spend considerable time on administrative tasks, including writing and updating patient records. After transcription of the remote consultation, AI-driven tools can automate clinical note structuring, ensuring that essential details from the consultation are accurately captured and recorded in the patient's EHRs. This automation saves time and minimizes the risk of human error, leading to more reliable and comprehensive documentation.[12] Moreover, AI and NLP technologies enhance the quality and structure of clinical records, which is vital for communication among care teams. In the multidisciplinary environment of modern healthcare, where various specialists may be involved in a patient's care, having complete and well-structured records is essential for making informed clinical decisions. NLP can standardize and categorize the information within patient records, ensuring that all relevant details are accessible and easy for any care team member to interpret.[13] Such capabilities are particularly valuable in telemedicine, where the physical separation of care providers can complicate communication and coordination efforts. Another critical area where AI and NLP can significantly impact post-consultation is the ongoing monitoring of patients and ensuring adherence to treatment regimens. Aharon et al.[14] demonstrated that an AI-based engine that generated recommendations and messages improved cardiac rehabilitation patient adherence. Complementary, Kirchner et al.[15] concluded that AI can also empower patients to take greater control of their health by ensuring that they fully understand diagnosis, treatment options, and self-care instructions at home. In addition, AI-driven tools can also analyze data from various sources, including wearable devices and patient-reported outcomes, to monitor patients' adherence to prescribed treatments and their response to those treatments at home. Such proactive approaches to patient management can reduce the

incidence of complications and improve overall treatment outcomes. Furthermore, the strategic application of AI and NLP post-consultation can significantly enhance the efficiency of telemedicine services. By automating routine tasks such as categorizing clinical information, AI allows healthcare providers to focus more on patient care than administrative duties. This improved efficiency can lead to shorter patient wait times, quicker follow-up actions when necessary, and better patient and provider experience. Additionally, with AI handling much of the data processing, there is less chance of missing important clinical details, leading to safer and more effective patient care.

Moreover, personalized care can be extended after a remote consultation. AI-powered virtual healthcare assistants are revolutionizing the healthcare industry by offering personalized patient care and alleviating the burden on healthcare providers. These digital assistants, which include applications, chatbots, and intelligent interfaces, simulate human conversation to assist patients with various tasks, such as identifying symptoms, providing mental aid, reminding patients to take medications, scheduling future appointments, and monitoring vital signs. By collecting daily health information and forwarding it to physicians, these tools support continuous and personalized patient care. Furthermore, their availability around the clock ensures that patients can access healthcare whenever needed. AI-driven applications are also being used to triage patients, determining the urgency of their conditions based on symptoms, as demonstrated by the British National Health Service, where over a million people now use an AI chatbot for medical remote inquiries.[16] Additionally, AI-powered chatbots enhance patient education by providing personalized and interactive information on diet, smoking cessation, and chronic disease management. These tools help patients better understand their diagnoses and treatment options, improving adherence and health outcomes. For instance, AI chatbots have been shown to increase knowledge about conditions like prostate cancer and diabetes, empowering patients to take control of their health. However, challenges such as ensuring AI-provided information's accuracy, reliability, and privacy while maintaining empathy in patient interactions remain critical. Post-consultation, AI, and NLP continue to play a vital role by automating documentation, improving the quality of clinical records, and ensuring patient adherence to treatment plans. These technologies enhance workflow efficiency and improve patient outcomes by facilitating continuous, personalized care.

The challenges in using AI and NLP as supporting tools for remote consultation in telemedicine

As remote consultation expands, significant emphasis must be placed on data privacy and security implications. Integrating AI and NLP technologies in telemedicine brings opportunities and risks related to patient data. Concerns surrounding unauthorized data access and breaches have surfaced, partially due to inadequate safeguards in digital health infrastructure, which poses a risk to sensitive patient information. Data suggest that 1 out of 4 cyberattacks were in the healthcare industry,[17] while 90% of hospitals and

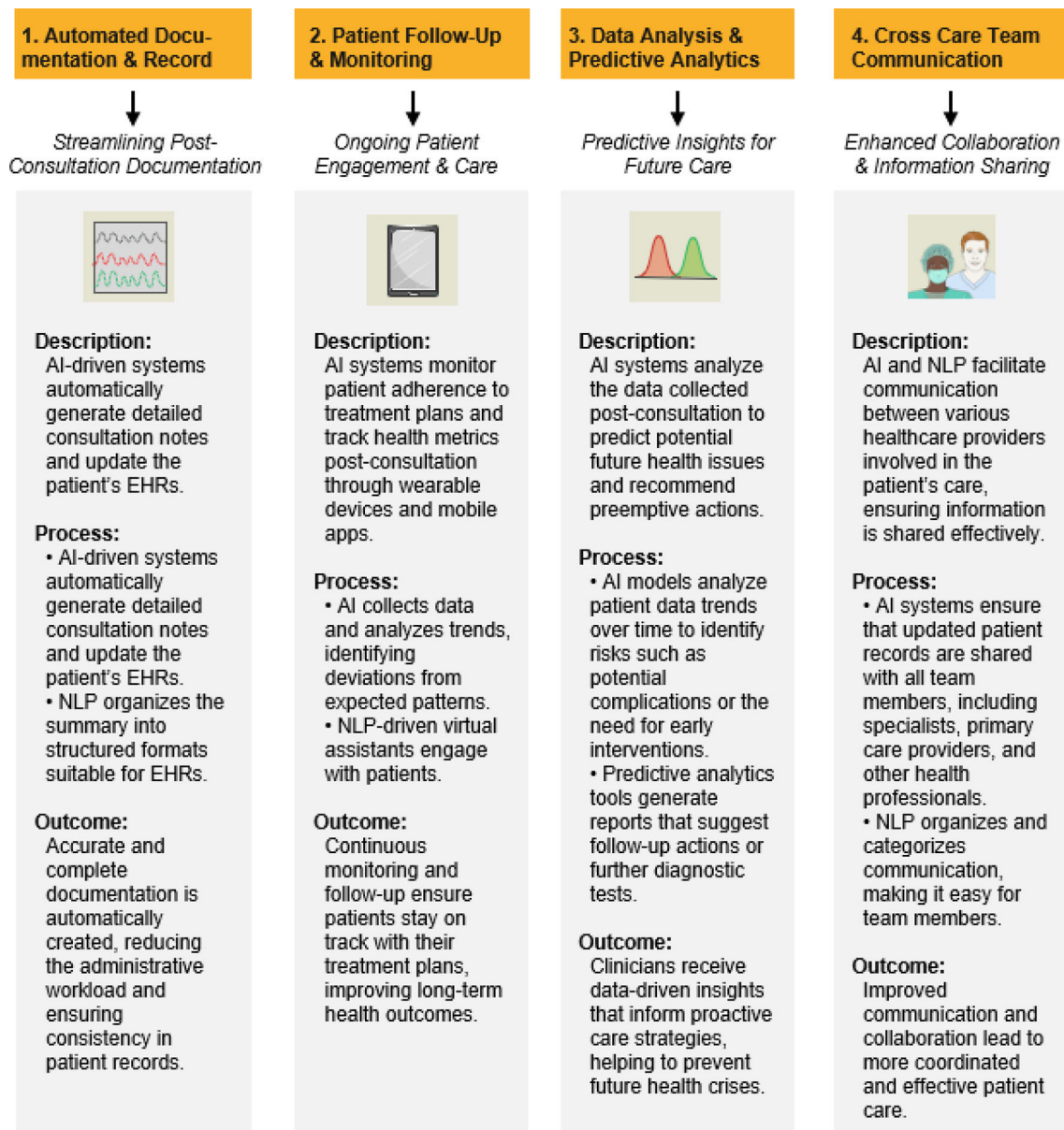| 1. Automated Documentation & Record	2. Patient Follow-Up & Monitoring	3. Data Analysis & Predictive Analytics	4. Cross Care Team Communication
Streamlining Post-Consultation Documentation	*Ongoing Patient Engagement & Care*	*Predictive Insights for Future Care*	*Enhanced Collaboration & Information Sharing*
Description: AI-driven systems automatically generate detailed consultation notes and update the patient's EHRs.	**Description:** AI systems monitor patient adherence to treatment plans and track health metrics post-consultation through wearable devices and mobile apps.	**Description:** AI systems analyze the data collected post-consultation to predict potential future health issues and recommend preemptive actions.	**Description:** AI and NLP facilitate communication between various healthcare providers involved in the patient's care, ensuring information is shared effectively.
Process: • AI-driven systems automatically generate detailed consultation notes and update the patient's EHRs. • NLP organizes the summary into structured formats suitable for EHRs.	**Process:** • AI collects data and analyzes trends, identifying deviations from expected patterns. • NLP-driven virtual assistants engage with patients.	**Process:** • AI models analyze patient data trends over time to identify risks such as potential complications or the need for early interventions. • Predictive analytics tools generate reports that suggest follow-up actions or further diagnostic tests.	**Process:** • AI systems ensure that updated patient records are shared with all team members, including specialists, primary care providers, and other health professionals. • NLP organizes and categorizes communication, making it easy for team members.
Outcome: Accurate and complete documentation is automatically created, reducing the administrative workload and ensuring consistency in patient records.	**Outcome:** Continuous monitoring and follow-up ensure patients stay on track with their treatment plans, improving long-term health outcomes.	**Outcome:** Clinicians receive data-driven insights that inform proactive care strategies, helping to prevent future health crises.	**Outcome:** Improved communication and collaboration lead to more coordinated and effective patient care.

Figure 3   Post-consultation integration of AI and NLP in telemedicine.

clinics experienced at least one data breach, and 45% experienced at least five data breaches.[18] Furthermore, biases[19] inherent in AI algorithms and the lack of transparency[20] in data usage can exacerbate issues of trust and equity within healthcare systems. Robust regulatory frameworks and stringent cybersecurity measures are paramount to protect patient privacy while ensuring compliance with legal standards. Addressing these concerns is crucial for fostering patient confidence and enabling the full potential of AI and NLP to enhance telemedicine workflow and patient outcomes.

As integrating AI and NLP technologies into remote consultations becomes increasingly prevalent, a corresponding emphasis on training healthcare professionals is imperative. The successful deployment of these advanced tools to enhance documentation and workflow efficiency hinges on the adeptness of clinicians in utilizing such inno-

vations effectively. Recent findings[21] underscore significant gaps in digital skills among future and current healthcare providers, as evidenced in studies highlighting the necessity for comprehensive training programs that equip clinicians with the knowledge to navigate telehealth modalities confidently. Enhancing clinical practices through AI is only attainable if practitioners are well-versed in interpreting and leveraging these technologies for patient care, ensuring they can uphold quality and safety standards within their workflows. Furthermore, addressing the challenges associated with technology adaptation, such as potential biases and workflow disruptions, requires ongoing educational initiatives to foster resilience and adaptability among healthcare teams.

Finally, the effective implementation of AI and NLP in remote consultations necessitates a robust infrastructure encompassing technological tools, human resources, and

organizational frameworks. Central to this is the need for seamless integration of AI systems with healthcare providers existing workflows, as emphasized in studies highlighting the disconnect between technological advancements and clinical practices.[22,23] Establishing a user-friendly interface is critical, allowing healthcare professionals to engage with AI tools without extensive retraining. Furthermore, addressing ethical considerations is fundamental to fostering trust among patients and providers. Ethical AI systems must be designed to prioritize patient well-being and autonomy, allowing patients to feel confident that trustworthy, unbiased technologies are guiding their care. For healthcare providers, knowing that AI tools adhere to rigorous ethical and certified standards enhances their confidence in these systems, enabling them to rely on AI with the assurance that it complements their professional judgment rather than undermining it.[24] In sum, the successful deployment of AI and NLP in telemedicine hinges on a well-structured infrastructure that prioritizes integration, training, and ethical standards, ultimately fostering a more efficient healthcare environment.

Conclusion

The transformative potential of AI and NLP in telemedicine documentation and workflow cannot be overstated. By leveraging these technologies, healthcare systems can address prevalent inefficiencies, ultimately enhancing clinical quality and patient safety within primary care settings. Integrating AI and NLP automates repetitive documentation tasks and streamlines clinician workflows, enabling healthcare professionals to devote more time to patient care than administrative duties. Furthermore, implementing these systems yields considerable benefits, such as increased accuracy in documentation and improved access to patient data, which are crucial in telemedicine. However, as with any technological advancements, challenges related to data privacy, ethical considerations, and necessary training must be rigorously addressed to optimize deployment. Future research should continue to explore these dimensions while pushing for broader adoption of AI and NLP solutions in telemedicine.

Ethical considerations

This manuscript reviews existing literature and does not involve new research with human or animal subjects. Therefore, no ethical approval was required. The manuscript was conducted with respect to the original author's work, and all referenced studies were evaluated to ensure they met the appropriate ethical standards.

Funding

Conflict of interest

The author declares no conflicts of interest related to this study.

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