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Quality Medical Data Management by Using a Novel Open AI Architecture for Cancer Patients

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ABSTRACT

People in today's culture are continually exposed to factors that can lead to the development of major illnesses. Medical and health-related intelligent decision-support systems and services require the collection of complex data from large numbers of patients. Doctors and caregivers can't improve patients' quality of life with individualized recommendations unless they properly prepare multimodal data from patients for intelligent processing and make the results easy to understand. More sophisticated AI methods, like explainable AI, federated learning, machine/deep learning, and others, will allow for more efficient use of health and medical data in the future. An innovative Open AI architecture for intelligent medical data management is the main topic of this article, which is aimed at cancer patients. In order to train machine learning predictive models, it is necessary to gather data, arrange it correctly, and get it ready to use. Another important element is the intelligent interpretation and display of results regarding patients' quality of life, which are produced from machine learning algorithms. The building's design and construction were phases of a larger undertaking in which fifteen different institutions from eight different European nations took part.

Keywords: Dara Handling, medical data management, Open AI Architecture.

INTRODUCTION

Improved population health, increased patient experience, enhanced caregiver experience, and lower healthcare costs are the "quadruple aim" of healthcare, and achieving it is a tremendous challenge for healthcare systems worldwide [1]. Healthcare expenses are on the rise due to the growing number of people coping with chronic health conditions around the globe. In light of this, healthcare providers, payers, regulators, and governments must innovate healthcare delivery. In the wake of the worldwide pandemic, healthcare systems everywhere have an even greater challenge: they must not only "perform" (provide effective, high-quality care) but also "transform" (improve) healthcare on a massive scale by incorporating data-driven insights into patient treatment. The pandemic has again brought to light two issues that have been previously voiced by organizations such as the King's Fund and the World Health Organization:

An inadequate supply of trained medical personnel and inequitable access to appropriate treatment.

A handful of these demand-and-supply problems might have technological and AI-based healing solutions. Now is the perfect moment for healthcare and technology to join forces, as developments in mobile, the IoT, processing power, and data security usher in a new era of multi-modal data. Analytics powered by AI will revolutionize healthcare delivery methods using this data [2]. Specifically, cloud computing is paving the way for more trustworthy AI systems to integrate into routine healthcare processes.

Health businesses may now analyze far larger data sets with the use of cloud computing, which offers cheaper and faster processing capacity than their previous "on premises" equipment. In fact, many digital companies are aggressively pursuing partnerships with healthcare institutions to advance medical innovation powered by artificial intelligence, which is made feasible by cloud computing and other types of technological change [3].

As far as anyone can tell, our civilization is perpetually dealing with major stressful events and worldwide health crises (such as the COVID-19 pandemic, dengue fever, avian flu, etc.). Consequently, people encounter situations every day that have the potential to harm their health. Some research [4] shows a correlation between stressful life

events and health problems, while other research [5] shows that stressors increase the risk of serious diseases. There is an increase in the prevalence of comorbidities and multi-morbidity, and the average age of the population is rising [6]. In light of these facts, it is essential to develop state-of-the-art services, technology, and tools, and comprehensive, high-quality clinical/hospital information systems [7]. We must also increase awareness of the importance of caring for the health of the community. Improvements in health-related quality of life components should be the primary focus of therapy and follow-up for those who have survived serious diseases, according to all parties involved. Pain, loss of appetite, psychological issues, sexual dysfunction, and other basic quality of life components are significantly compromised during active oncological treatment and follow-up care for cancer patients, in addition to more prevalent health problems like anxiety, sleep disorders, mental impairment, etc. [8].

Through our ASCAPE project, we have created an innovative Open Architecture that utilizes AI and ML to provide patients with breast and prostate cancer individualized treatment plans. Three subsystems with comparable functionality are integrated into ASCAPE Open AI Architecture. In this paper, we will try to show how important it is to manage patients' data and how the first two subsystems of the ASCAPE architecture accomplished critical capabilities. Our architecture for individualized medical decisions also makes use of the Cloud/Edge methodology, which we will quickly outline key features of here [9].

AI In Healthcare

Artificial intelligence (AI) is revolutionizing patient monitoring, diagnosis, and therapy, marking a new age in healthcare. By facilitating more precise diagnoses and tailored treatments, this technology is transforming healthcare studies and results. With the help of AI, healthcare providers can quickly sift through mountains of patient records, uncovering trends and warning signs of disease that were previously hard to spot. From early diagnosis utilizing radiological image scanning to outcome prediction using electronic health data, artificial intelligence has a lot of potential uses in healthcare.

Thanks to healthcare systems' use of AI in hospitals and clinics, countless people's lives could be considerably improved.

As it turns out, AI is the wave of the future in healthcare, revolutionizing the way patients get high-quality treatment while simultaneously reducing provider expenses and enhancing health outcomes [10].

It all started with Watson, an AI system created by IBM to swiftly and effectively answer questions. Articles discussing AI in healthcare often reference IBM's 2011 release of Watson, a healthcare-focused version of the platform that prioritized NLP (human language understanding and interpretation). More and more capital is being invested by IT giants like Amazon, Apple, IBM, and Microsoft in healthcare AI solutions [11]. The potential for artificial intelligence to bring forth truly remarkable revolutions in healthcare is immense. The healthcare industry stands to gain much from the application of artificial intelligence (AI) in data processing, illness diagnosis, therapeutic development, and prevention. Healthcare practitioners may improve medical records administration, cut expenses, and save time by using AI to make better judgments with more accurate data. Artificial intelligence (AI) has the ability to change cancer treatments and improve patient experiences. This could lead to a future where patients can get first-rate care quickly and accurately [12].

LITERATURE REVIEW

In both traditional medical practise and cutting-edge research into smart health solutions, electronic health records (EHRs) serve as the backbone of patient information. The patient's clinical information, diagnoses, medications, treatments, and other relevant data is preserved in these records, which allow for a more thorough and continuous assessment of the patient's health. To provide a fuller picture of a patient's health, they also use data from non-traditional sources, such as nutritional and exercise tracking, as well as Patient Reported Outcome Measure (PROM) surveys. In order to get more complete datasets and trustworthy processing outcomes, it is essential to gather patient data from a variety of different sources [13]. In this regard, the CrowdHEALTH initiative stands out (Gallos et al., 2019). The primary goal is to create a Holistic Health Record by integrating patient data from several sources. According to Kyriazis et al. (2017), the project aims to provide a comprehensive platform that uses big data management techniques such as data gathering, cleaning, integration, modeling, analysis, information extraction, and sufficient, powerful interpretation. Similar big data management techniques are used in the ASCAPE project, which likewise includes data gathered from numerous sources in patient records.

Machine Learning

When it comes to medical diagnosis and treatment, machine learning—a subset of artificial intelligence—has been a game-changer. Algorithms can examine massive volumes of clinical data, find trends, and forecast medical outcomes with remarkable precision. Healthcare providers can enhance treatments while reducing costs with the help of this technology, which analyzes patient information, medical imaging, and finds new therapies. Accurate illness diagnosis, individualized treatment plans, and the ability to identify even minute changes in vital signs that may signal possible health problems are all made possible by machine learning [14]. The most common application is in precision medicine, which analyses patient data and utilizes supervised learning to determine the best course of therapy. Deep learning, a subfield of AI, has various medical uses, one of which is speech recognition powered by natural language

processing. Healthcare providers will need to comprehend and use deep learning in clinical contexts more and more as the technology develops.

Natural Language Processing

One subfield of AI, known as "natural language processing," makes it possible for machines to understand and mimic human speech. The usage of this type of AI in healthcare is revolutionizing the sector. Improved patient care through more accurate diagnoses, streamlined clinical procedures, and more tailored services are just a few of the many health data applications that are making use of natural language processing [15]. When applied to medical records, natural language processing (NLP) can help doctors make more precise diagnoses by gleaning relevant information from patient records. Further applications include the prediction of future health hazards based on previous health data and the identification of appropriate therapies and drugs for individual patients. In addition, natural language processing gives doctors effective resources for handling complex data sets, a task that would otherwise take a lot of time to accomplish by hand. Natural language processing is rapidly becoming an essential tool in healthcare by allowing clinicians to use AI for more accurate disease diagnosis and more personalized patient treatment. This medical AI is already indispensable in today's healthcare system, and it's only going to get better and find more uses in the future.

Rule-based Expert Systems

The bulk of healthcare AI developed in the 1980s and the decades that followed relied on "if-then" rule alterations. Clinical decision support is still a popular use of AI in healthcare today. There are currently a number of EHRs that come with their own set of rules and regulations.

In most cases, engineers and subject-matter experts work together to construct a comprehensive set of rules for an expert system. Up to a point, they serve their purpose well and are simple to understand and work with [16]. However, regulations might start to clash and disintegrate when their number becomes excessively high, typically beyond several thousand. Changing the regulations might also be a pain if there is a big shift in the field of expertise.

Diagnosis and Treatment Applications

The bulk of healthcare AI research and development over the past half-century has focused on disease detection and therapy. Even though there was some initial doubt, early rule-based systems showed a lot of promise for accurate disease diagnosis and treatment. They weren't any more accurate in diagnoses than humans, and they had problems integrating with medical record systems and physician workflows.

Using AI for diagnosis and treatment planning can be hard when it comes to integrating algorithmic or rule-based AI systems into healthcare workflows and electronic health record systems.

The widespread use of AI in healthcare has been hindered, not by the accuracy of recommendations, but by issues with integration into healthcare organizations. The artificial intelligence (AI) and healthcare skills of many medical software businesses are fragmented and dedicated to certain areas of treatment, such as diagnosis, therapy, and clinical trials [17]. There are a few early adopters of artificial intelligence (AI) healthcare analytics features in EHR software, but this is just the beginning. To effectively leverage AI in healthcare with a standalone EHR system, providers will have to pour significant resources into integration projects or look for third-party vendors who can interact with their EHR and have AI capabilities.

Administrative Applications

The development and implementation of AI is revolutionizing numerous facets of healthcare administration. As a result of AI automating routine tasks like data entry, claims processing, and appointment scheduling, healthcare organizations and clinicians may be able to spend more time on patient care and revenue cycle management. Additionally, AI can improve the efficiency of medical data, imaging, claims processing, and evaluations of test results, all of which contribute to a decrease in human error. With the help of AI, medical professionals may exert greater command over their workflow processes, allowing them to deliver cost-effective, high-quality care to patients [18].

By quickly and accurately evaluating patients' medical histories, artificial intelligence (AI) is transforming healthcare. As a result, doctors are free to focus on their patients more.

As AI continues to revolutionize healthcare, doctors and other medical staff may rest easy knowing they can save time and money by automating administrative work and focusing on providing high-quality treatment to patients. The use of AI in healthcare ultimately provides a more efficient and effective means for medical professionals to attend to their patients' needs. Artificial intelligence can automate repetitive administrative chores, allowing medical practitioners to save time and money while having more control over their workflow.

CHALLENGES FOR ARTIFICIAL INTELLIGENCE IN HEALTHCARE

Healthcare companies are investing heavily in AI for a variety of purposes, but this technology raises several ethical and regulatory questions that may not apply in other industries.

The most pressing issues surrounding artificial intelligence in healthcare include protecting sensitive patient information, ensuring the correctness and safety of patient data, teaching algorithms to identify trends in medical records, incorporating AI into existing information technology systems, winning over physicians' confidence and approval, and meeting all applicable federal requirements.

Due to the potential for misuse of the vast quantities of personally identifiable health information collected by AI systems, data privacy is of the utmost importance. Furthermore, adequate security protocols should be established to prevent unauthorized individuals from accessing and using sensitive patient information.

Using AI in healthcare raises fundamental questions about accuracy and patient safety. Training is necessary for AI systems to make accurate, patient-specific suggestions, comprehend the interrelationships between various diagnoses and treatments, and identify trends in healthcare data. Incorporating AI with existing IT systems could add another layer of complexity for healthcare providers, since it necessitates a thorough comprehension of how the technology works to guarantee proper functioning.

Finally, medical practitioners' trust and support are crucial for AI to be a success in healthcare. In order for AI to provide reliable advice, doctors must have trust in it. Therefore, transparency is essential; physicians must understand the reasoning behind the AI system's findings in order to confirm that they are grounded on credible, up-to-date medical research. It is critical to adhere to government regulations in order to guarantee the ethical use of AI systems and the prevention of harm to patients.

When Did AI Become Popular in Healthcare

The advent of AI in healthcare has been a watershed moment in the history of medicine. The use of artificial intelligence (AI) in healthcare has grown in importance over the last decade, becoming an essential component of cutting-edge medical practices all around the globe. By delving into AI's uses, advantages, and revolutionary healthcare AI instances, we can better understand when and how AI became so vital. There were huge leaps forward in technology and data analysis around the turn of the millennium, which led to artificial intelligence (AI) in healthcare attracting a lot of attention. A confluence of factors, including rising computing power, the availability of massive datasets (Big Data), and remarkable advancements in AI-driven medical algorithms, occurred during this time. But the real light bulb moment occurred when we saw how AI could solve some of healthcare's biggest problems, including inefficient operations, inaccurate diagnoses, and lack of individualized therapy.

The artificial intelligence healthcare industry was worth $11 billion in 2021, but according to Statista, it's projected to reach $187 billion by 2030. Because of this meteoric rise, the healthcare industry as a whole—including doctors, hospitals, pharmaceutical and biotech firms—should brace itself for major operational shifts in the near future.

How AI is Reshaping Decision-Making

Although many in the medical field see AI's revolutionary potential, many are wary of implementing it in patient care just now. The majority of doctors (83%) think AI will be good for healthcare in the long run, although a sizable minority (70%) are worried about its diagnostic applications. We should be cautiously optimistic about AI's potential to improve patient outcomes, notwithstanding these legitimate worries. In order to build trust and confidence in the use of AI in healthcare, it is essential to understand its advantages and disadvantages and put appropriate protections in place.

Clinical decision-making and administrative operations are two areas where artificial intelligence is already making waves in the healthcare industry. It paves the way for proactive action by physicians by identifying trends across large populations, which in turn leads to individualized treatment that improves health outcomes generally. AI has several uses outside direct patient care, including research, managing populations' health, and improving the patient experience. Healthcare providers may find a middle ground between the advantages of AI and the necessity to safeguard patient data thanks to new technology and stringent regulations that assist reduce risks associated with data privacy and security.

THE BENEFITS OF AI IN HEALTHCARE

Due to its ability to collect and analyze vast quantities of medical data at a rate that exceeds human skills, AI may completely transform the healthcare system.

Disease diagnosis, outcome prediction, and treatment recommendation all benefited greatly from this skill. For example, artificial intelligence systems can examine magnetic resonance imaging (MRI) and X-rays more quickly and accurately than human radiologists, and they can frequently spot cancer and other diseases in their early stages. The use of AI in healthcare is widespread and has far-reaching consequences. Beyond IBM's Watson Health, another noteworthy advancement was Google's DeepMind Health project, which proved to be able to diagnose ocular disorders from retinal scans as accurately as human specialists. These ground-breaking initiatives demonstrated how artificial intelligence may transform personalized medicine and diagnostics.

The realm of AI applications in healthcare goes much beyond just diagnostics. When used to healthcare, AI is revolutionizing areas such as drug research, administration, and patient care management. Chatbots and virtual assistants powered by artificial intelligence can help patients stay engaged and follow their treatment plans by providing constant assistance and monitoring. Artificial intelligence (AI) dramatically reduces the time and money needed for clinical trials by fast-tracking the drug discovery process and correctly predicting how different drugs would interact with the body.

One further area where AI has made a big splash in healthcare is predictive analytics. In order to predict potential health risks, AI systems can examine medical histories and current health data for trends. By enhancing patient outcomes and decreasing healthcare expenditures, predictive skills have made proactive and preventative care

possible for healthcare practitioners. Artificial intelligence streamlines numerous processes in healthcare facilities. The whole gamut, from scheduling patients to processing insurance claims Robots powered by artificial intelligence allow doctors and nurses to spend more time with patients and less time on paperwork. Overall, patients have a better experience, and operations run more smoothly. The application of artificial intelligence (AI) in healthcare has been steadily increasing, propelled by both technological advancements and the increasing need for improved healthcare delivery.

A paradigm shift has occurred as a result of AI's incorporation into healthcare, which has improved efficiency, accuracy, and personalization. Artificial intelligence's already substantial impact in healthcare is only going to grow as the technology matures, establishing AI as an essential component of contemporary medicine. From an abstract idea to an integral part of healthcare, AI has gone a long way, and it promises to improve everyone's health. This is an example of a technological revolution.

ETHICAL IMPLICATIONS

At last, the application of AI in healthcare raises a number of important ethical questions. Humans have traditionally been the sole decision-makers in healthcare, and the introduction of smart devices to either make or aid in these decisions brings up concerns about privacy, openness, accountability, and transparency.

When considering modern technology, transparency may be the most challenging issue to resolve. There are a lot of AI algorithms that are really difficult to understand and describe, especially deep learning algorithms that are used for picture analysis. The rationale behind the use of an image to diagnose cancer is likely to be of interest to the patient if told of it. Both deep learning algorithms and doctors with a general understanding of how they work might not be able to explain it. When it comes to patient diagnosis and treatment, AI systems will make mistakes—and it might be hard to hold them accountable.

Sometimes, patients may prefer to speak with a compassionate doctor, but AI systems end up giving them medical advice they don't want. Healthcare machine learning systems could potentially be biased by algorithms, leading to inaccurate illness risk predictions based on gender or ethnicity. There will be several technological, medical, ethical, and occupational shifts as a result of AI in healthcare. In order to mitigate potential negative effects, healthcare organizations, along with government and regulatory agencies, must put systems in place to track critical issues, respond responsibly, and govern effectively. One of the most potent and consequential technologies ever to influence human civilizations, it will require persistent attention and thoughtful policymaking for quite some time.

METHODOLOGY

The ASCAPE – Architecture of Intelligent System

Modernly structured as a cloud/edge computing platform, ASCAPE supports privacy-preserving AI/ML/FL approaches.

The ASCAPE Cloud and, in theory, an unlimited amount of ASCAPE Edge nodes make up this (see to Figure 1). Four Edge nodes, representing the participating health institutions in the project, are part of the current prototype that is being tested and used. At the edge nodes, the ASCAPE Cloud coordinates the training of global models for Federated Deep Learning and trains models for Homomorphic Deep Learning using data that has been homomorphically encrypted. Federalized Deep Learning, which acquires models on a worldwide scale, and ASCAPE both use modern ML technologies that protect users' privacy. To build this type of model, data may be collected from every FL Edge node locally, eliminating the need to upload data to the cloud or train a global model with data from individual Edge nodes.

With Homomorphic Deep Learning, data encrypted in a homomorphic fashion at the edge can be used to train models in the cloud. The output produced by such models can be homomorphically decrypted when utilized for inference with input data that is homomorphically encrypted. Only the cooperating Edge node knows the secret key utilized for encryption and decryption; the Cloud remains in the dark. Which is why only Edge nodes that have swapped keys can encrypt and decode data. One major benefit of this method is that it allows you to train and infer models using ASCAPE Cloud without actually getting your hands on any unencrypted data. Doctors will be able to make better, more patient-specific decisions with the help of the proposed ASCAPE Open AI architecture, which provides the fundamentals for a number of HISs and medical systems.

Numerous components for implementing various functionalities are contained in the fundamental building blocks. By incorporating the ASCAPE widgets and supporting backend code, an existing HIS can transmit patient data to ASCAPE. This gives the HIS the same ASCAPE functionality as the standalone ASCAPE Dashboard and allows doctors to take advantage of ASCAPE's extra benefits.

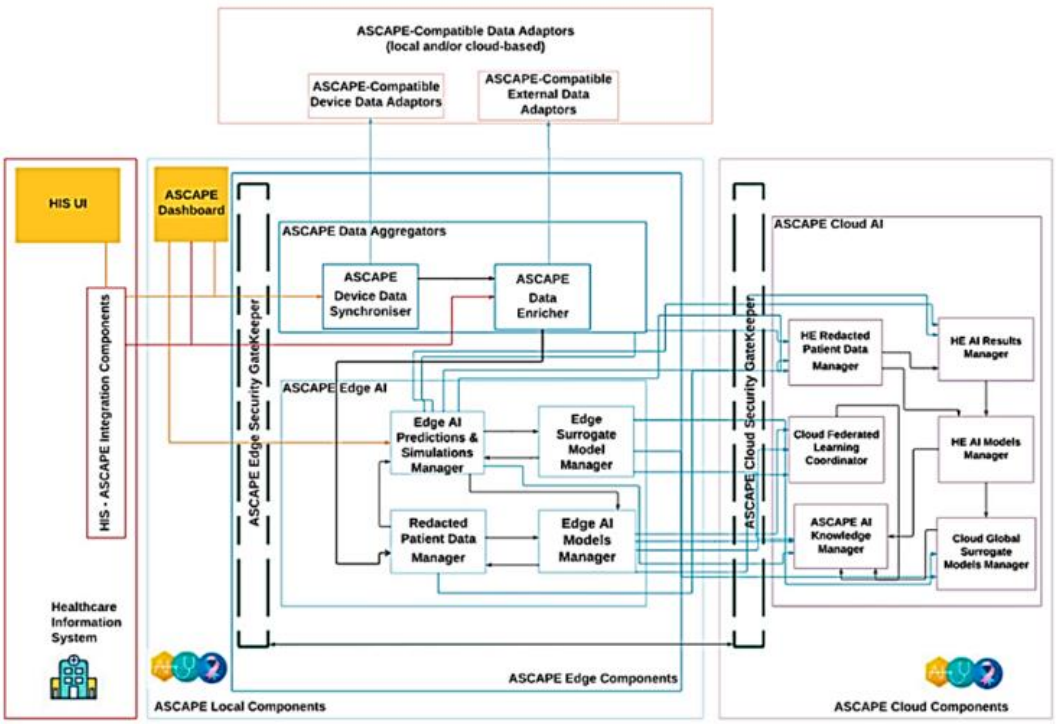


Figure 1. *The ASCAPE AI architecture.*

By utilizing the ASCAPEData Aggregators, supplementary patient data that is not gathered by the HIS (but rather by ASCAPE-compatible Data Adaptors installed either locally or remotely, for example, in smart devices) can be transmitted to the ASCAPE Edge node. If the HIS does not effectively integrate ASCAPE, clinicians can still access ASCAPE capabilities through the ASCAPE Dashboard. These capabilities include AI-assisted monitoring of patients' QoL states and recording information about prospective therapies. The ASCAPE Cloud oversees the process of teaching all participating health institutions, or "Edge nodes," how to work together in a way that respects patients' privacy. With the help of the HIS and the Dashboard, the ASCAPE Edge Components function together.

All the collaborating healthcare institutions can benefit from the collectively trained predictive models in this way. To provide optimal compatibility with firewall settings seen in ICT environments of healthcare institutions, all contacts between the ASCAPE Cloud and components on edge nodes are started from the edge nodes towards the cloud.

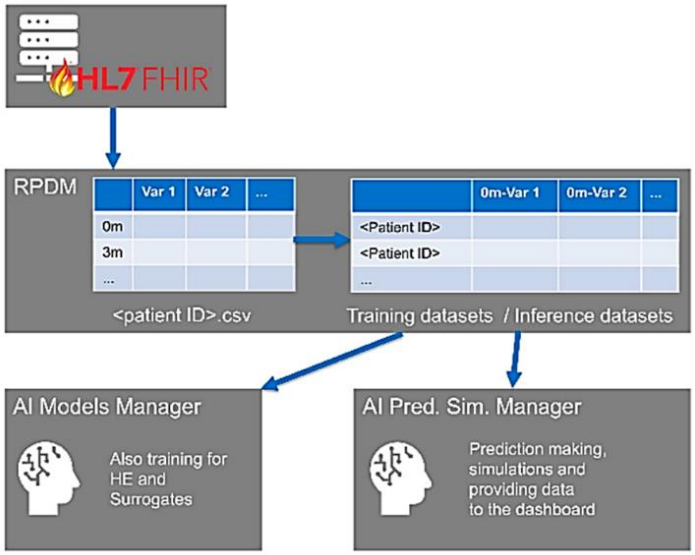


Figure 2. *A medical standard-based ASCAPE data model.*

For the purpose of implementing privacy-preserving ML technologies, the following ASCAPE Cloud Components can be utilized: (i) FL coordination and storage; (ii) training and storage for models on homomorphically encrypted

data and encrypted predictions; and (iii) components for collaborative surrogate model training, which are XAI techniques utilized within ASCAPE. Secure component-to-component communication is made possible with the help of ASCAPE's Security GateKeeper, which supplies auditing, authorization, and centralized authentication. User and component level access can be managed in a flexible and extensible manner.

We are primarily focused on facilitating integration with HIS user identities that adhere to specified authentication protocols. Methods like SNOMED CT and the International Classification of Diseases (ICD) can help find certain data in the medical and health fields. For the most part, ASCAPE makes use of the latter to catalog patient records' variables, or characteristics (see Figure 2).

RESULTS AND DISCUSSION

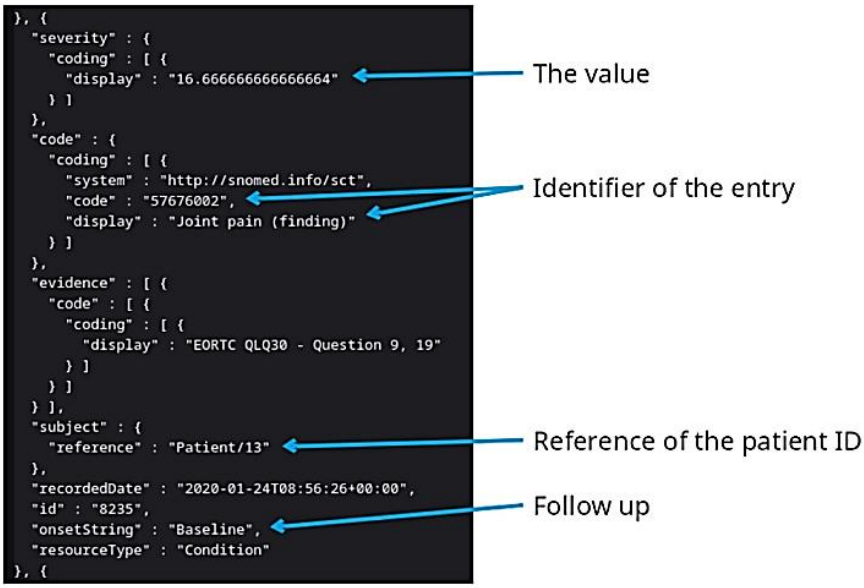
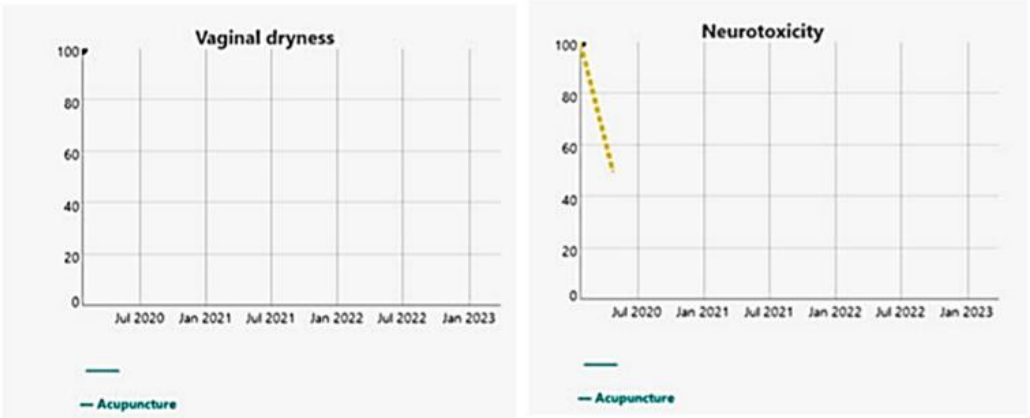


Figure 3. *Part of a patient's data in structured format.*

The training datasets are first homomorphically encrypted and then uploaded in CSV format to the ASCAPE Cloud. The next step is to apply privacy-enhancing techniques, such as differential privacy and outlier identification. Figure 3 shows a sample of the data that fits the description so far.

AI/ML role in the ASCAPE architecture

The ASCAPE showcases a fascinating and cutting-edge design that addresses all of these points. Its primary objective is to equip doctors with an AI-driven tool that tracks and forecasts a patient's quality of life metrics related to their overall quality of life and individual features, as well as provides recommendations for treatments that may enhance results. The ASCAPE Dashboard, which serves as the main interface, was developed to assist doctors in providing better post-treatment assistance to cancer patients. It does this by efficiently and meaningfully presenting recorded and predicted data values visually. In reality, when doctors engage with the ASCAPE system, data about individual patients is gathered and shown, including predictions for their overall and individual quality of life (QoL) and interventions proposed by AI, ML, and FL. Figure 4 shows the finished ASCAPE customized visualisations widget (Deliverable D4.1) from the ASCAPE system.



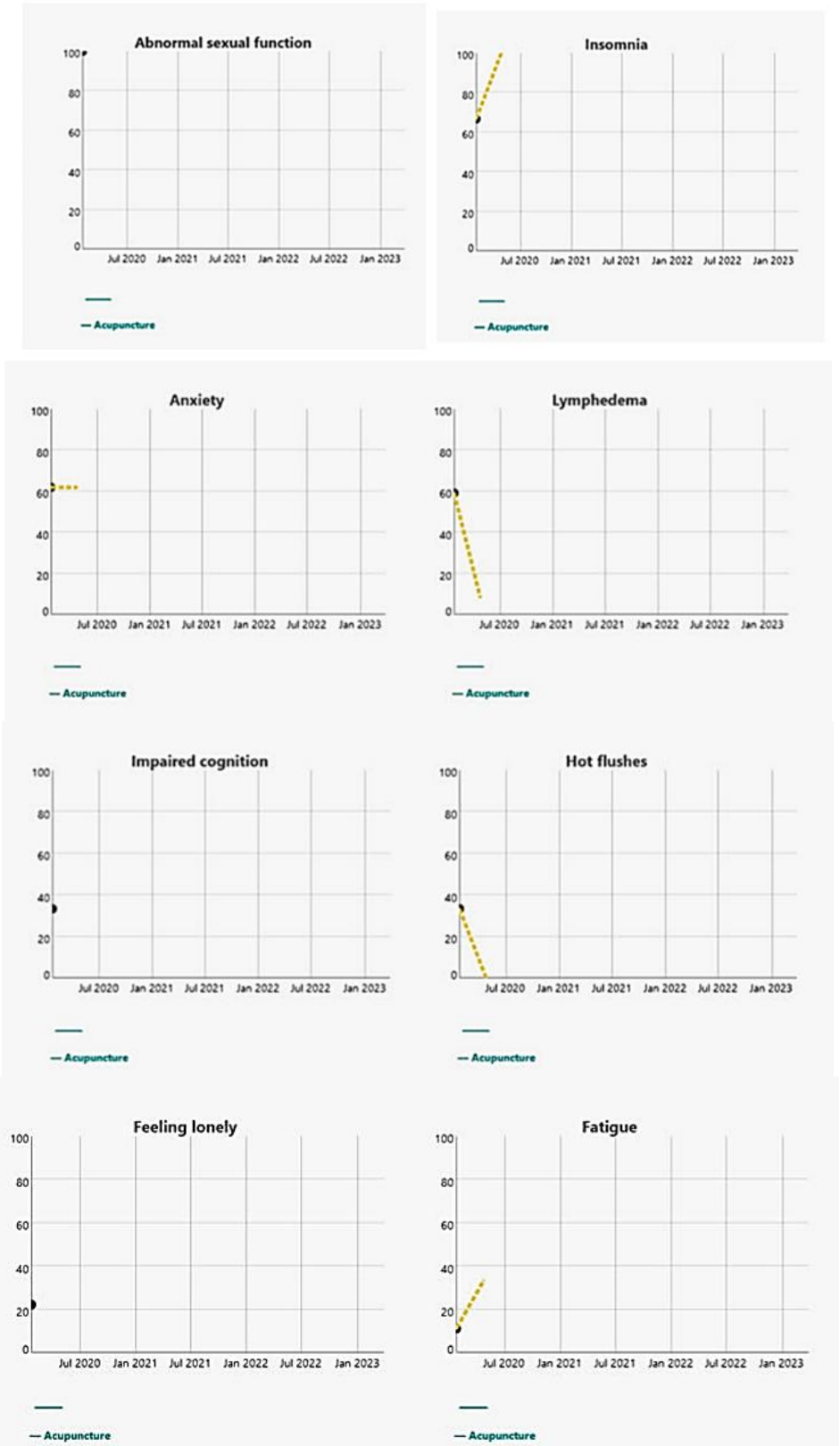


Figure 4. *The patient visualisations widget of the ASCAPE system.*

CONCLUSION

In this work, we want to present the groundbreaking ASCAPE Open AI Architecture and its key features, focusing on how they pertain to patient data management in particular. This includes not only simplifying the presentation of results to doctors and caregivers, but also pre-processing data to use as input for training and evaluating AI/ML models. The entire system has now been tested with data from previously treated patients (retrospective datasets). We

are anticipating accurate and dependable behavior from the constructed architecture as we continue our research with evaluation of the architecture on data gathered from new patients (prospectively collected data), following the extremely encouraging results obtained in this method. In our experiments with the ASCAPE design, we used XAI approaches to display the data at the dashboard, and the results were quite encouraging. If ASCAPE is successful, it will lead medical research and practice in highly visible directions.

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