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EARLY PREDICTION OF NEONATAL EPILEPSY BY USING ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

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ABSTRACT
Neonatal epilepsy syndromes are serious medical conditions that are frequently associated with structural, genetic or neuro-metabolic disorders. With timely diagnosis and treatment to mitigate the risks of neurodevelopmental impairment or other long-term complications. Due to the rapid MOVEMENTS in Artificial Intelligence (AI) and Machine Learning (ML), new opportunities arise for improving early diagnosis and more patient-specific functioning of neonatal epilepsy.
Ai is the broad umbrella term for technology that simulates human cognition thought processes, reasoning ability and decision making in which applications are being integrated into epilepsy care. Its transformative role is through real-time seizure detection, enhanced diagnostic accuracy, and tailored treatment strategies. Machine learning and deep learning models can transform the interpretation of Early electroencephalography (EEG), automating up to 80 percent of this type of analysis, which compares two intricate brain wave patterns, whilst minimizing human error. These systems can monitor continuous EEG data, detect signals with high risk of seizure generation, and even make a prediction when the seizure will occur before visually identifiable clinical signs are present.
ML techniques also achieved excellent performance when analyzing large, multicenter datasets to evaluate preliminary clinical signs and EEG characteristics. Given this, the use of such early prediction methods is valuable in cases like that of hypoxic-ischemic encephalopathy (HIE) where seizures can occur and prevention or intervention may be required.
Clinicians can shift from reactive to proactive care models by harnessing these technologies. This transition holds significant potential in alleviating the burden of neonatal epilepsy.
Neonatal care can improve when the very early prediction and treatment of epilepsy through AI and ML, which greatly enhances outcomes for patients.

KEYWORDS: Neonatal epilepsy, Artificial Intelligence, Machine Learning, EEG analysis, Seizure prediction, Hypoxic-ischemic encephalopathy, Early diagnosis

1. INTRODUCTION

Self-limited neonatal epilepsy, early myoclonic epileptic encephalopathy, and Ohtahara syndrome are among the seizure disorders that fall under the umbrella of neonatal epilepsy. These disorders are frequently associated with underlying anatomical or genetic problems. Neonates frequently experience seizures, especially during the first month of life. Compared to full-term babies, preterm babies are more prone to having neonatal seizures.[1] A class of electroclinical syndromes known as neonatal epilepsy syndromes is deemed medically urgent since it may be a sign of underlying structural or neuro-metabolic abnormalities. While some of these conditions become better with time, others can have serious neurodevelopmental effects that increase morbidity and mortality.[2] The majority of newborn seizures that take place during the first month of life are acute in nature. In the first month of life, most newborn seizures are acute symptomatic. A lesser percentage of neonatal seizures are caused by neonatal epilepsy disorders.[3] Appropriate therapy must be started after a prompt and precise diagnosis.[4] In certain metabolic early onset neonatal epilepsies, early detection using a systematic diagnostic methodology is essential because it allows for targeted treatment; otherwise, seizures are frequently drug-resistant, and the results are frequently unfavorable.[5] Healthcare will change as artificial intelligence (AI) becomes more prevalent in society. To safely and successfully integrate these tools, neonatologists need to comprehend AI ideas. In neonatology, AI may enhance diagnosis, care, and outcome prediction.[6]

2. Understanding Neonatal Epilepsy Syndromes

Neonatal epilepsy syndromes are seizure diseases that manifest in the first month of life and exhibit distinct patterns in the appearance or behavior of seizures as well as brain testing. These syndromes are distinct from acute symptomatic seizures, which are seizures brought on by obvious triggers, such as brain traumas. A newborn's brain is still developing throughout the first month of life because many symptoms manifest during this time. Therefore, compared to other age groups, newborn seizures have a distinct etiology and electrographic findings that can lead to different (and more challenging) clinical symptoms.[7] Inborn errors of metabolism, neuro-metabolic syndrome, genetic problems, and structural abnormalities are among the common causes of neonatal epilepsy syndrome.

Structural abnormalities

Neonatal epilepsy frequently results from structural brain abnormalities. Schizencephaly, porencephaly, hemimegaloencephaly, subcortical band heterotopia, lissencephaly, and polymicrogyria are some examples of these abnormalities.[1] With the growing use of head ultrasound (HUS) and high-resolution magnetic resonance imaging (MRI), congenital and developmental structural brain abnormalities have gained wider recognition and have been linked to neonatal seizures.[8]

Genetic disorders

Neonatal seizures can result from a few genetically based inborn metabolic abnormalities. A hereditary disorder known as benign familial newborn epilepsy (BFNE) is characterized by seizures that start in the first few weeks of life in a kid who is otherwise healthy and has a normal neurological evaluation. This disorder is typically caused by pathogenic variations in genes that code for voltage-gated channel subunits and have autosomal dominant inheritance.[9] One of the most common hereditary causes of epilepsy is tuberous sclerosis complex (TSC), which frequently manifests as refractory episodes. Of those with TSC, 75–90% of those have epilepsy.[10]

Neuro-metabolic syndromes

A significant class of illnesses known as neurometabolic disorders primarily affects neonates and babies. While epilepsy is a common symptom of neurometabolic disease, neurometabolic disorders are not a common cause of epilepsy. This category of epilepsy includes a variety of seizure forms and EEG patterns. Particularly in newborns and early infants, epilepsy can be a noticeable sign of neurometabolic abnormalities.[11] The likelihood of a particular medication to alleviate epilepsy is increased when neurometabolic abnormalities in epileptic patients are accurately diagnosed. When aberrant neurological examination and brain imaging show certain patterns, neurometabolic disorders should be taken into consideration in epileptic patients who have developmental delay and/or regression.[12]

Because newborn seizures are a strong indicator of long-term cognitive and developmental damage, they are the subject of several scientific and clinical studies.[13] Particularly in the context of HIE, neonatal seizures represent a substantial risk factor for long-term consequences. Long-lasting seizures have been demonstrated to exacerbate brain damage in HIE brains, suggesting that seizures may be damaging in and of themselves. Negative neurodevelopmental consequences are often the consequence of HIE linked to status epilepticus.[14] Seizures in neonates are linked to a higher chance of dying and long-term morbidity in survivors.

3. Challenges in Early Diagnosis and Management

Early Neonates with seizures are difficult to diagnose and need a comprehensive evaluation that includes laboratory testing, magnetic resonance imaging, electroencephalography, history, and physical examination. More seizures occur during the neonatal era than at any other time in life. However, seizures can also be mistaken for normal infant activities, making identification more difficult. Both undertreatment and overtreatment of newborn seizures can negatively impact the neurological development of the infant, therefore an incorrect diagnosis can have major repercussions.[1] Less than 50% of seizures are eliminated by first-line anticonvulsant medication (phenobarbitone or phenytoin), which has proven to be an extremely disappointing approach to managing newborn seizures. Although they need additional research, medications like lidocaine and midazolam may further lessen seizures.[15,16]

Because newborn seizures can be brief and mild, diagnosing them can be challenging. Furthermore, the symptoms of seizures can resemble the typical actions and movements of healthy babies. Clinical observation alone is not enough to diagnose neonatal seizures; EEG proof is required. Some neonates have early-onset structural or metabolic/genetic epilepsy, even though most seizures in newborns are caused by severe brain injury. Neonatal seizures are still difficult to diagnose.[16]

A diagnostic technique used to examine neonatal brain maturity and neurologic problems (such as encephalopathy and seizure disorders) is neonatal electroencephalography (EEG). The postsynaptic potential of neuronal axons is measured by EEG.[17] With increasing gestational maturity from preterm to full term post-menstrual ages (PMAs), newborns' neurophysiological development can be demonstrated using Approximate and Sample Entropy to quantify the complexity of their EEG sleep.[18]

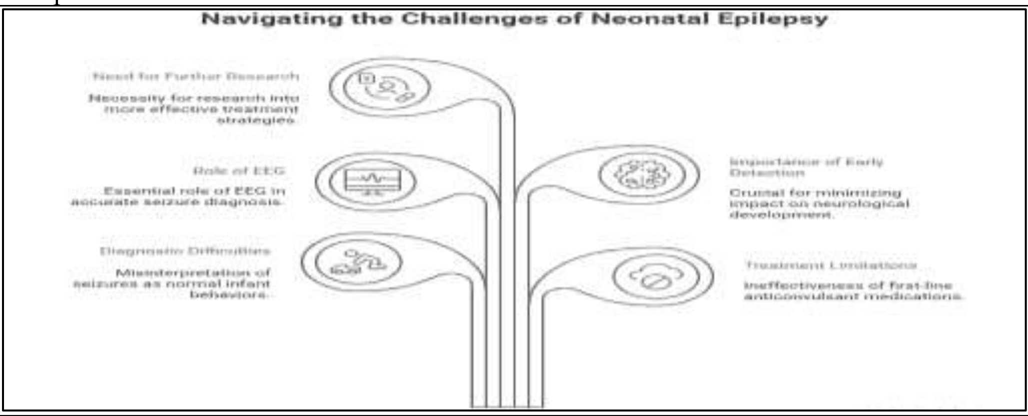

Fig 1. Challenges in Early Diagnosis and Management of Neonatal Epilepsy

Early seizure detection and diagnosis is crucial to reducing CNS or systemic effects of serious infection. Anytime during the neonatal era, acute seizures brought on by infections, such as herpes simplex virus infection or late group B streptococcal infection, might happen.[8] In certain situations, normal developmental outcomes might result from early diagnosis and suitable treatment. Since an early diagnosis promotes a better response to treatment, it may offer a window to reduce the impact of seizures on the developing brain. Treatment will depend on when and how long EEG monitoring is started, as well as how accurately seizures are identified.[19]

4. AI and ML: Concepts and Relevance in Neonatal Epilepsy

The science and engineering of creating intelligent machines, particularly intelligent computer programs, is known as artificial intelligence (AI). AI does not have to limit itself to techniques that are observable in biology, but it is tied to the comparable challenge of utilizing computers to study human intelligence.[20] As a branch of artificial intelligence (AI), machine learning (ML) focuses on teaching algorithms to predict or decide based on input data. Large datasets are used to train machine learning algorithms so they can identify trends and reach conclusions. Children's epilepsy has been successfully diagnosed with artificial intelligence (AI). One viable way to improve diagnostic precision and maximize therapeutic approaches for epilepsy is through the application of AI and ML technology.[3] Artificial intelligence (AI) applications in pediatric epilepsy use a variety of datasets, such as electronic health records (EHRs), magnetic resonance imaging (MRI) scans, and electroencephalogram (EEG) recordings, categorizing seizure types, locate focal lesions, forecast treatment outcomes, and improving patient care pathways.[21]

Both symbolic reasoning and sub-symbolic processing are used in AI to simulate human thought, enabling machines to learn from sparse data, make context-aware decisions, and adjust to changing conditions. To improve decision-making and goal-oriented behavior, cognitive AI systems frequently integrate memory systems, attention mechanisms, and reinforcement learning. The capacity to analyze intricate patterns from vast volumes of data and produce rational "rules" for using fresh data to make judgments, predictions, or adjustments is a key advantage of contemporary artificial intelligence programs. Researchers studying artificial cognition have been able to create models with superhuman capability in a variety of domains because to this data-driven methodology.[22]

Deep neural networks are used by DL, a more sophisticated subset of ML, to process high-dimensional, complicated data, including EEG recordings and neuroimaging scans (MRI, PET). Because deep learning (DL) can build effective feature representations from raw data, it has shown considerable promise in helping interpret EEG signals. In the treatment of epilepsy, Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) are frequently used to locate epileptogenic zones and improve seizure detection.[23] In addition to aiding in the identification of brain problems, Deep Learning (DL) techniques used to EEG signals also make it easier to identify human emotions and a variety of psycho-neuro disorders.[24] Unlike a single neuron network with a single hidden layer, a deep neural network is created with multiple hidden layers. This indicates that the output is the result of a multi-layer non-linear transformation of the input data.[25] Effective brain system characterization from EEG signals is possible thanks to deep learning and complex networks' potent analysis capabilities.

5. Applications for AI/ML in Neonatal Epilepsy Care

With better diagnosis, individualized care, and early problem prevention, artificial intelligence (AI) has enormous potential to revolutionize neonatology. There are chances to use AI algorithms to real-time and store data to enhance newborn outcomes. The development of AI-derived automated neonatal seizure detectors (NSDs) has been made possible by advancements in artificial intelligence (AI). These devices have the potential to improve the fast and accurate identification of newborn seizures, especially in settings with limited resources. AI algorithms are acceptable to personnel, can be used in the NICU, and—most importantly—more seizures were recognized in real time since they are "always on." Up until now, most seizure detection algorithms have been created for full-term neonates; however, several are already being developed for preterm infants.[26]

Real-Time Seizure Detection

More precise detection, prognosis, and individualized treatment regimens are made possible by AI technologies. For instance, real-time analysis of EEG patterns by AI-driven seizure detection algorithms enhances monitoring for patients requiring constant observation.[27] Applications of AI/ML include identifying behavioral and autonomic seizure surrogates, identifying interictal epileptiform activity, and predicting seizures for preventative measures. Additionally, segmentation accuracy for accurate electrode placement can be improved by AI-powered neuroimaging analysis, which can lead to better neuromodulation results.[28]

The electroencephalogram (EEG) is a crucial tool for diagnosing epilepsy and for identifying and localizing episodes. Automated seizure detection has been investigated using machine learning (ML) models based on electroencephalogram (EEG) inputs. Large volumes of EEG data can be analyzed by ML algorithms, which may be able to spot minute patterns linked to epileptic activity that human experts could overlook.[5,6] This has made it possible to create automated, objective EEG analysis systems that could increase diagnostic precision and expedite clinical procedures.[29] ML shows a lot of promises for seizure identification based on EEG. When ML is included in imaging and monitoring equipment, it can be a potent tool for early epilepsy diagnosis and prompt treatment.[30]

AI algorithms offer a lot of promise for accurately detecting and tracking pediatric epilepsy, frequently meeting clinical standards. Overall diagnostic sensitivity is increased by AI, particularly in situations with unusual presentations. When compared to traditional EEG analysis alone, AI-integrated systems can raise seizure detection rates by 20% to 30%, which makes them a useful tool for difficult cases or situations with a shortage of expert resources.[27] When it comes to identifying newborn epilepsy, artificial intelligence (AI) and machine learning (ML) offer significant advantages. Compared to conventional techniques, they can make seizure detection quicker, more precise, and more effective.

EEG Interpretation and Analysis

An EEG test looks for anomalies in the electrical activity of the brain, or brain waves. Through potential differences between electrodes placed over the scalp, the EEG captures electrical activity produced by cerebral neurons. The EEG is converted to digital form, amplified (generally between 20 and 100 µV, as in a healthy adult), filtered to eliminate or minimize noise (usually between 0.3 and 70 Hz), and shown as waves with different shapes and frequencies. Although visual inspection is typically used to interpret these waveforms, quantitative measurement of the frequency, amplitude, topographical distribution, cross correlation, and reactivity can also be used to objectively measure cerebral activity.[31]

The speed-up factor of the EEG sonification is modulated by the AI probabilities, allowing for a rapid pass over lengthy background EEG segments while keeping the emphasis on the EEG regions of interest (potential seizures). To improve the perception of seizures—which are mapped into longer duration in the acoustic domain than the rest of the EEG data—AI adjusts the pace at which the audio is played again.[32]

Due to its ability to detect tiny patterns in large volumes of data recorded in different channel signals, machine learning technology is gaining particular attention as a means of efficiently processing EEG data.[33] This is especially crucial for EEG-based identity recognition, since distinguishing between people requires identifying minute patterns and characteristics in brain signals. By examining patterns of electrical activity, the electroencephalogram, or EEG, can assist in identifying high-risk signals associated with certain brain disorders. Spikes, sharp waves, or slow waves are examples of abnormal EEG patterns that could indicate conditions including epilepsy, brain tumors, or stroke.

In clinical management and the development of novel therapeutic options, such as warning or intervention devices, seizure prediction is crucial. Finding the preictal time that electroencephalogram (EEG) signals can record is the goal of seizure prediction systems. Several models have been developed to predict seizures. They attempt to forecast when a seizure will occur by using relevant characteristics as indicators of approaching seizures. Certain characteristics are shared by all seizure prediction models. Most of them require two steps. Initially, they all attempt to identify and extract EEG-based measurements throughout time that describe the interictal, preictal, and postictal phases of the epileptic cycle. To do this, they employ a moving window analysis, which computes a linear or nonlinear characterization measure from an EEG data window of a predetermined duration. The analysis windows typically last between 10 and 40 seconds. Differentiating and categorizing the measures into preictal and ictal states is the second stage.[34]

Data-Driven Clinical Insights

Data-driven seizure detection integration is absent from the current digital care pathway for epilepsy (DCPE), which could improve differential diagnosis and treatment for patients who are resistant to medications. Significant advancements could be possible with the incorporation of data-driven technology, such as improved management of medication-resistant epilepsy, collaborative decision-making, individualized treatment plans, and more precise seizure detection and prediction.[35] By using machine learning and artificial intelligence to evaluate enormous volumes of patient data, such as EEG, video, and other physiological signals, data-driven clinical insights are transforming seizure detection and enabling more precise, timely, and individualized seizure detection and prediction.

Over the past five years, studies have presented EEG-based seizure detection and prediction algorithms that primarily rely on publicly available EEG-based datasets. Studies frequently employ oversampling and under sampling strategies to get over this restriction and enhance the ML model's performance because ML techniques necessitate larger and more balanced samples. A model's likelihood of incorrectly categorizing seizure cases from out-of-sample data can be decreased by using sufficiently powered datasets that cover a wide variety of seizure forms.[36] Datasets are essential for creating and assessing machine learning-based seizure detection systems. Researchers may train models to identify patterns linked to seizures and distinguish them from normal brain activity using these datasets, which frequently include Electroencephalogram (EEG) recordings.

Using a sizable multicenter data set, machine learning techniques are used to evaluate the predictive power of early clinical characteristics and EEG background variables for infants with HIE who go on to experience seizures. We postulated that the optimal machine learning model to identify which infants with hypoxic-ischemic encephalopathy (HIE) would be at risk of seizures would combine early clinical data with EEG background variables.[37] Differentiating between electroencephalographic (EEG) and clinical aspects might help doctors make diagnoses more quickly. intended to identify the clinical and EEG characteristics that distinguish stroke from HIE in infants experiencing seizures.[38]

6. Benefits of AI/ML Integration

Improved long-term results, less seizure burden, and earlier seizure therapy are some possible advantages of AI/ML.[6] The diagnosis, tracking, and treatment of epilepsy could be greatly enhanced by recent developments in artificial intelligence (AI). Electroencephalography data has been analyzed using machine learning approaches for effective seizure detection and prediction. Individualized treatment has also been utilized to provide early and tailored intervention for people with epilepsy.[39]

By increasing the precision and effectiveness of epilepsy diagnosis and treatment, AI presents encouraging alternatives. Algorithms for machine learning (ML) and deep learning (DL) can help with automating EEG analysis, anticipating the onset of seizures, and customizing treatment regimens based on patient data.[27] By providing insightful information about creating cutting-edge diagnostic instruments for clinical use, AI increased diagnosis accuracy. The landscape of AI applications in clinical care is changing because of the increasing availability of various datasets, improved processing speed, and continuous efforts to standardize reporting.[40]

Numerous research, particularly those that use machine learning (ML) approaches, have shown promise in improving early diagnosis, which is important for early detection and understanding of the severity of epilepsy. Precise algorithms can help with early and accurate diagnosis, which could enhance epilepsy treatment and lessen the psychological strain brought on by unpredictable seizures.[41] The intricacies of managing epilepsy are addressed by machine learning and deep learning technologies, which enhance seizure monitoring, automate EEG analysis, and enable customized therapy approaches.[27]

New research indicates that a variety of factors, including HIE, metabolic disorders, structural brain abnormalities, and hereditary channelopathies, might trigger seizures in newborns. Precision therapy, which customizes therapies according to genetic and biochemical profiles, is becoming more popular because of this understanding. Although treatment frequently begins based on clinical indications, early genetic testing such as Whole Exome Sequencing (WES)/Whole Genome Sequencing (WGS) is essential because over half of neonatal epilepsies have genetic roots. Early administration of sodium channel blockers, such as carbamazepine or oxcarbazepine, may avoid damage in suspected channelopathies and effectively control seizures in 70–80% of patients, particularly in certain genetic epilepsies. The significance of these medications in reducing seizures and averting long-term neurological consequences is shown by their success rate. This emphasizes the necessity of switching from reactive to proactive therapy, in which diagnostic factors—rather than a trial-and-error method—are used to guide initial management.[42]

7. Case Studies and Emerging Research

More accurate seizure predictions have been made possible by recent research that has made use of developments in computational techniques. For example, Wei et al. used multichannel EEG signals and a long-term recurrent convolutional network (LRCN) with a long short-term memory (LSTM) block to extract features. They were able to predict pre-ictal segments with a sensitivity of 91.88% and an accuracy of 93.4%.[43] High specificity (93.33%–96.67%) and good sensitivity (93.33%–76.67%) were achieved with a hybrid approach in which human raters used operational criteria for interictal epileptiform discharge (IED) on AI-detected events. The accuracy was comparable to traditional EEG readings, but the time burden was greatly reduced.[44] SVM achieved the best reported accuracy of 98.4% in a different comparative study that assessed many machine learning algorithms for seizure detection tasks, including K-Nearest Neighbors (KNNs), Random Forest, Decision Tree, and SVM.[45]

The integration of artificial intelligence (AI) and machine learning (ML) into newborn epilepsy clinical practice has advanced significantly in recent years, especially in the areas of neonatal seizure detection and treatment. The ANSeR system (Algorithm for Neonatal Seizure Recognition), which analyzes EEG data using deep learning and provides real-time seizure notifications, is among the most prominent examples. To highlight its utility in the common clinical sphere, ANSeR reduced by almost half the number of false-negatives in diagnosing infants with electrographic seizures (improved from 45% under usual care to 66% when utilized as a clinical decision-support tool within a multicenter trial across eight European neonatal intensive care units).[46] Similarly, O'Shea et al. (2017) showed how user-friendly the output of AI systems should be when they field tested a neonatal seizure detection algorithm and found that physicians recommended combining probabilistic traces with simple binary alerts. Models have shown good predictive accuracy (AUC from 0.746 to 0.832), using machine learning techniques to predict seizure risk in hypoxic-ischemic encephalopathy (HIE) newborns [51]. These models provide a useful tool for improved resource management and EEG monitoring prioritization.[37] Moreover, the latest research has focused on explainability of AI solutions: effort of models to visually show what EEG features influence an algorithm decision by using салiency maps and a reduced set of EEG montages, which improves physician understanding and trust.[47] The development of large high-performing convolutional neural networks capable of learning from large EEG datasets is another important advance; these models have already shown expert-level performance in seizure identification and are ready for wider clinical translation.[48] Overall, these developments illustrate the expanded use of both AI and ML in reducing neonatal epilepsy, opening pave for enhanced monitoring, early detection and enhanced clinical decision-making.

In the field of imaging research within epilepsy, many studies have explored different machine learning approaches (ranging from logistic regression to linear discriminant analysis and support vector machines). Neural networks have evolving from single-layer, two-layer and multi-layer neural networks to more complex structures such as deep neural network (DNN), making them increasingly popular for application in imaging studies for epilepsy.[49] Future developments in artificial intelligence applications can focus on designing models that specifically detect electrographic phenocopies of various types of epilepsy (e.g., spikes, high-frequency oscillations, seizures). Optimizing epilepsy treatment may be possible by integrating AI to analyze EEG data in addition to clinical and behavioral data.[50] Creating multimodal AI systems that include EEG and ECG data for better seizure recognition in various contexts could potentially be an advancement.[51]

Study	Method	Accuracy/Sensitivity	Notes
Wei et al.	LRCN with LSTM on multichannel EEG signals	Sensitivity: 91.88%, Accuracy: 93.4%	High specificity achieved with hybrid approach
Hybrid Approach	Human raters using operational criteria	Specificity: 93.33%–96.67%, Sensitivity: 93.33%–76.67%	Comparable to traditional EEG readings
Comparative Study	Various ML algorithms including SVM, KNN, Random Forest, Decision Tree	Best Accuracy: 98.4%	SVM achieved the best reported accuracy

ANSeR System	Deep learning analysis of EEG data	Accuracy improved from 45% to 66%	Used as clinical decision-support tool in multicenter trial
O'Shea et al. (2017)	Neonatal seizure detection algorithm	AUC values: 0.746 to 0.832	Emphasized user-friendly interface
Machine Learning Models	Predict seizure risk in newborns with HIE	AUC values: 0.746 to 0.832	Useful for resource management and EEG monitoring prioritization

Table 1. Case Studies and Emerging Research on AI/ML in Neonatal Epilepsy

8. Ethical and Practical Considerations

Several ethical concerns, including data security, algorithm openness, and accountability, are raised using machine learning to identify epilepsy in children. These elements are essential to preserving patient and healthcare provider confidence. To avoid negative results that go against ethical medical practice standards, the ethical challenges also extend to research design and algorithm selection.[41] Laws and regulations like the Health Insurance Portability and Accountability Act (HIPAA) in the US and the General Data Protection Regulation (GDPR) in Europe outline stringent standards for data security and patient privacy in healthcare.[52] To protect patient information, such rules mandate encryption, restricted access and the anonymization of data. Newer methods of privacy-preserving AI, such as differential privacy and federated learning, allow AI models to learn using data without having direct access to the underlying patient data. These techniques mitigate privacy risks by keeping private data on-device, in addition to only sharing aggregate insights.[27]

Algorithmic biases can be relevant since most algorithms have been trained within adult data sets. It is critical to use pediatric datasets when training and validating models, as these biases may lead to misdiagnoses or incorrect treatment recommendations for children.[53] Ensuring that these AI systems generalize and are equitable in clinical settings requires considering the potential for model bias resulting in error across diverse patient populations. Thus, while these advancements show promise, the success of AI in healthcare will ultimately boil down to finding the middle ground between technological advances and ethical dilemmas.[54] Patently, rigorous evaluation and adjustment of AI algorithms is needed to ensure the biases that confer disparate treatment effects for diverse patient populations are eliminated.[55]

Having large, diverse datasets for training and validation is key to the effectiveness of AI-based diagnosis in epilepsy. Certain AI models' intricacy leads to "black box" problems, in which the models' internal decision-making processes cannot be fully understood. Clinicians may find it challenging to verify AI advice and bring up moral concerns regarding accountability in misdiagnosed situations due to this lack of transparency.[27] It is difficult to get regulatory approval for machine learning equipment. The US FDA now has more authority to authorize and control machine learning software.[3] Only a small number of AI technologies have been authorized and put into use in the NICU. Only eight of the approximately 692 AI-enabled devices, or "software as a medical device," that the FDA had approved as of Fall 2023—mostly in radiology—had been given reimbursement codes by the Centers for Medicare and Medicaid Services.[6]

Even though AI is said to perform better than humans, physicians should nonetheless oversee real-world judgments. As a result, this AI model's primary function is to increase diagnostic precision by supporting physicians in their treatment choices.[56] Skilled medical professionals are adjusting to AI by changing the conventional diagnostic procedure rather than substituting it. They are creating a new method that starts with AI's recommendation and proceeds backwards by evaluating its validity against several verification stages, as opposed to merely accepting AI's diagnostic output or "label." This entails comparing patient information, confirming against accepted medical norms, and seeking advice from additional specialists. By using AI's capabilities while upholding clinical rigor and control, physicians are not only keeping their crucial role but also improving the diagnosis process.[57]

9. Future Perspectives

The optimum use of AI would be as hybrid intelligence (also known as human-in-the-loop or mixed intelligence) to improve the feasibility of neonatal care, improve diagnosis accuracy, and anticipate outcomes and disorders. Future neurologic issues and possible hazards may be addressed by AI-based predictive analysis technologies. Monitoring systems with AI support could simultaneously examine and identify changes in real-time data from monitors.[58] Rapid developments in networking, data storage, and technology offer chances to use AI technologies to build "smart" NICUs.[6] These resources may be useful for "family centered care" as well as standard NICU care.

Clinical prediction, which forecasts health outcomes by using past and present medical data, is essential to modern healthcare. Better patient outcomes and increased healthcare efficiency result from the application of artificial intelligence (AI) in this industry, which also greatly improves illness prevention, treatment planning, diagnostic accuracy, and individualized care. Algorithms using artificial intelligence (AI) can spot correlations and patterns that humans would miss. Over time, these algorithms predicted accuracy increase since they are built to continuously learn from and get better at new data.[59] Research on the neuromonitoring of critically ill neonates has increased in recent decades. Artificial Intelligence (AI) and machine learning (ML) in particular have enabled computer systems to examine and analyze vast amounts of data, including medical patterns, primarily applied to magnetic resonance imaging (MRI) and electroencephalograms (EEG).[60] Furthermore, EEG monitoring aids in the separation of clinical and EEG seizures following antiseizure therapy by identifying any electrical discharge that might continue after therapy while the clinical epileptic manifestation that might have existed prior to treatment vanished. Although real-time examination and implementation of EEG can be difficult, EEG records the electrical activity of the cerebral cortex non-invasively, enabling the evaluation of cortical background function in real-time.[61]

Therefore, AI/ML can reduce human labor and enhance continuous EEG monitoring, effectively allocating medical resources. AI is anticipated to become a vital component of the neonatal care toolset, assisting parents/caregivers and healthcare professionals in delivering safer, more effective, and better neonatal care. To make this a reality, HCPs must become more digitally literate in order to comprehend the principles and limitations of AI. Additionally, cross-disciplinary, international collaborations involving data and computer scientists, HCPs, lawyers, and policymakers are required to design and implement AI tools that will address the issues raised.[26] By combining AI with wearables and IoT technology, neonates might be monitored in real time at home, cutting down on hospital visits.[62]

10. CONCLUSION

The application of artificial intelligence (AI) and machine learning (ML) in neonatal epilepsy is significantly changing the way we diagnose, follow, and treat this complex condition. One of the biggest advantages of these technologies is their potential to detect and predict seizures more quickly and accurately than traditional methods. These sophisticated techniques, such as deep learning and automated seizure detection systems, allow artificial intelligence to analyze volumes of complex data from MRIs, EEGs and medical records for patterns that indicate an increased risk of seizures. This capability allows for real-time monitoring, warning of early seizure start, and the detection of very small variations in brain activity that a physician would not be able to monitor or sense. AI is beneficial if used early on to analyse whether the patient have severe illnesses like hypoxic-ischemic encephalopathy (HIE) and help medical professionals act as earlier possible possibly keeping long-term brain damage in check. Moreover, AI prediction models allow medical teams to cease responding to seizures after they have already occurred and rather forewarn and prevent them, leading to more customized treatment as well as serving the need. All together, these technological advances represent movement towards more proximate, targeted and effective care for neonates with epilepsy.

Maximising the potential of AI and ML for newborn care, however, isn't something that can be done in isolation. There are many specialists, including neonatologists, pediatric neurologists, biomedical engineers, computer scientists, data experts and regulatory professionals who need to work collaboratively. Close collaboration is essential to ensure these technologies are developed that truly meet clinical needs, retain appropriate ethical integrity, and integrate with realities of neonatal practice. Moreover, human judgment remains invaluable; though AI agents offer valuable information, doctors must still assess and confirm these results to ensure safe and effective treatment. To resolve issues, such as algorithm bias—especially when models are trained with adult data—we need to add pediatric-specific information into the equation. It also requires legal and policy experience in navigating rules, privacy protections and transparency. When communication and sharing of knowledge are encouraged across disciplines, clinicians will be more comfortable using AI tools. This will ensure that technology augments their professional judgment instead of substitute it." This kind of interdisciplinary collaboration is vital for the safety of patients and for breakthroughs in newborn neurology.

In the future, artificial intelligence and machine learning could play a significant role in achieving better outcomes for infants with newborn epilepsy. Thrilling advances are already in the works, from apps that help customize drug regimens and allow doctors to monitor babies remotely through smart devices to systems that read EEGs and predict seizures in real time. In coming years, hybrid systems which utilize machine intelligence and human knowledge will surely serve to enhance diagnostic and treatment decisions. The ability of more sophisticated AI models to detect early subtle signs of epilepsy could lead to increasingly personalized treatment. In addition, innovations such as wearable tech and smart NICUs will keep newborns healthier at home longer and improve the quality of life for newborns (and their families). The key issues will be ensuring equitable access to the technologies, rigorous data security, and build strong international cooperation. Ultimately, appropriately using AI and ML may be a gamechanger in reducing seizures and improving long-term neurologic outcomes among the most vulnerable patients.

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