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A Shallow Review of Artificial Intelligence Applications in Brain Disease: Stroke, Alzheimer's, and Aneurysm

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Abstract

Artificial Intelligence (AI) has emerged as a transformative tool in the field of neurology, offering innovative solutions for the diagnosis, treatment, and management of brain diseases. This review provides a focused examination of AI applications in three critical areas: stroke, Alzheimer's disease, and aneurysms. By analyzing recent advancements in machine learning algorithms, deep learning models, and neural networks, this paper highlights the significant impact of AI on improving diagnostic accuracy, predicting disease progression, and personalizing treatment plans. In the context of stroke, AI has been instrumental in enhancing imaging techniques and predicting patient outcomes. For Alzheimer's disease, AI-driven tools have shown promise in early detection and monitoring of disease progression through the analysis of neuroimaging and clinical data. In the case of aneurysms, AI applications have improved detection and risk assessment, facilitating timely and effective interventions. Despite these advancements, the review also addresses the ethical considerations, challenges, and limitations associated with the integration of AI in clinical practice. This shallow review aims to provide valuable insights for researchers, clinicians, and policymakers, fostering further exploration, and implementation of AI technologies in the management of brain diseases, and commercial platforms in brain disorders imaging.

Keywords*:* Brain Stroke, Alzheimer's disease, Aneurysm, Artificial Intelligence, Brain Disorders

Introduction

These days, Artificial Intelligence (AI) has revolutionized various fields such as lung [1] and breast [2] cancer, teeth disease [3], arthritis [4], cosmetic and reconstructive breast surgery [5], embryo detection [6], and also including neurology. This paper aims to review AI applications in diagnosing and managing three critical brain diseases: stroke, Alzheimer's disease, and aneurysms. The focus is on recent advancements from 2019 to 2024, highlighting the impact of AI on diagnostic accuracy, disease progression prediction, and personalized treatment plans.

Stroke

Brain Stroke also known as a cerebrovascular accident (CVA), is a critical medical condition where the blood flow to the brain is disrupted, resulting in a lack of oxygen and nutrients for brain cells [7]. This can happen due to a blockage (ischemic stroke) or a burst blood vessel (hemorrhagic stroke). Without prompt treatment, brain cells start to die, which can result in brain damage, disability, or even death. Stroke symptoms may include sudden numbness or weakness in the face, arm, or leg, particularly on one side of the body, confusion, difficulty speaking, vision problems in one or both eyes, and loss of balance or coordination. Prompt medical attention is essential to reduce brain damage and enhance recovery prospects [8]. Artificial Intelligence (AI) has significantly advanced the diagnosis and management of ischemic stroke, particularly through the enhancement of imaging techniques and predictive models. Such as infarct or hemorrhage detection, segmentation, classification, large vessel occlusion detection, and prognostication [9]. AI algorithms, especially those based on deep learning, have been instrumental in the early detection of ischemic strokes by analyzing complex imaging data from CT and MRI scans [10]. These algorithms can automatically segment infarcted areas, identify large vessel occlusions, and assess the extent of brain damage with high accuracy [11]. Additionally, AI-driven systems have been developed to guide treatment decisions, improving the selection of candidates for thrombolytic therapy and mechanical thrombectomy [12]. Predictive models utilizing AI can forecast patient outcomes, such as the likelihood of recovery and potential complications, thereby aiding clinicians in developing personalized treatment plans [9].

Alzheimer's Disease

Alzheimer's disease (AD) is a neurocognitive disorder that primarily affects individuals aged 65 and older, but recent evidence shows that the age range is expanding to younger [13]. Over the next 40 years, the number of Alzheimer's disease cases is anticipated to grow from 27 million to 106 million, affecting one in every 85 individuals globally [14]. AI-driven tools have shown promise in early detection and monitoring of Alzheimer's disease through neuroimaging and clinical data analysis [15,16]. AI models, particularly those utilizing deep learning, have been developed to analyze brain imaging data, such as Magnetic resonance imaging (MRI) scans, positron emission tomography (PET), diffusion tensor imaging (DTI), biomarkers, and cerebrospinal fluid (CSF) [17]. Currently, MRI images are primarily used for diagnosing Alzheimer's disease (AD) to identify early signs of Alzheimer's with high accuracy [13]. A study at Massachusetts General Hospital demonstrated that an AI model could detect Alzheimer's disease risk with 90.2% accuracy using routinely collected clinical brain images [18]. The emerging field of explainable AI (XAI) aims to make these models' predictions more interpretable for medical practitioners, thereby increasing their trust and adoption in clinical settings. AI tools are also being used to predict the progression of Alzheimer's disease, offering a more accurate prognosis compared to traditional clinical methods [19]. Convolutional neural networks (CNNs) are highly effective in processing neuroimaging data, and extracting critical pathological features to assist doctors in detecting disease progression [20].

Aneurysms

Cerebral Aneurysm known as a brain aneurysm is an abnormal bulge or ballooning in a blood vessel in the brain due to a weakened vessel wall. This condition can be life-threatening if the aneurysm ruptures, leading to bleeding in the brain, known as a hemorrhagic stroke. Intracranial aneurysms (IAs) are a significant public health concern. In populations without comorbidity and a mean age of 50 years, their prevalence is up to 3.2% [21]. Unruptured intracranial aneurysm remains a major public health concern affecting about 3%–7% of the general population. Early detection through imaging tests is crucial for managing the condition and preventing rupture. computed tomography angiography (CTA), magnetic resonance angiography (MRA), and digital subtraction angiography (DSA) are the preferred techniques to identify aneurysms [22]. AI applications by using deep learning methods have improved the detection and risk assessment of aneurysms, facilitating timely and effective interventions [23]. This tool is being used to assess the risk of aneurysm rupture by predicting pressures and stresses from blood flow images. And by predicting the prognosis and risk of recurrence, optimizing patient care and management workflows [24]. Thereby assisting in clinical decision-making and improving patient outcomes. Aneurysms, ischemic and hemorrhagic strokes, and brain changes after Alzheimer's disease are shown in Figures 1.

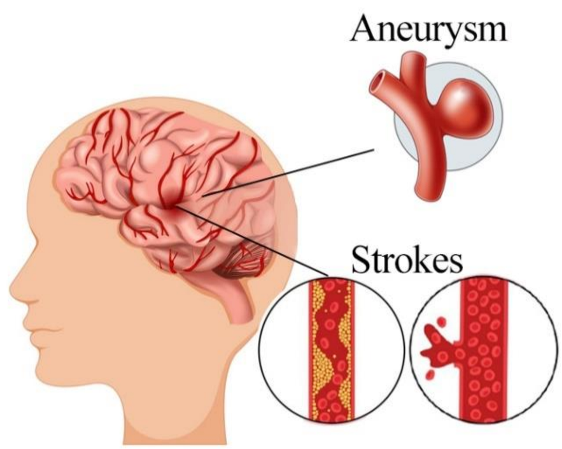

Fig1. Ischemic and Hemorrhagic Strokes

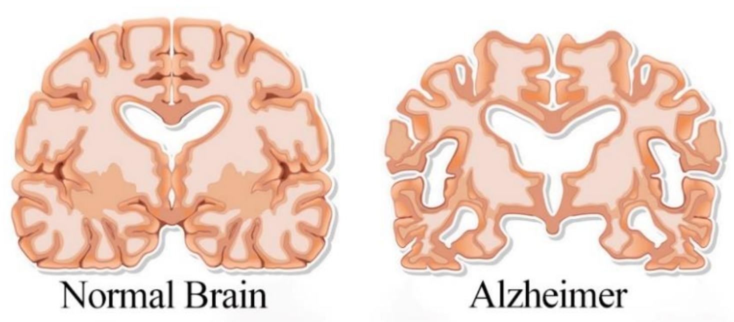

Figure 1 Alzheimer's Effect on the Brain

Search Strategy

Based on Meta-Analyses (PRISMA) guidelines, a comprehensive literature search was conducted using databases such as PubMed, IEEE Xplore, Scopus, and Web of Science. The search terms included combinations of "Artificial Intelligence," "Neural Networks," "Deep Learning," "Stroke," "Alzheimer's Disease," and "Aneurysm." The search was limited to English articles published between 2019 and 2024. Only peer-reviewed articles were considered to ensure the quality and reliability of the information. Data were extracted from the selected articles, focusing on image processing in AI technology, Specific applications in stroke, Alzheimer’s disease, and aneurysm, methodologies employed in the studies, results and outcomes of the AI applications, limitations, and future directions suggested by the authors. Finally, 22 publications were included in our review for new application surveying, also we have used other papers in background checks and discussions to have a rich literature review.

Discussion

Artificial Intelligence (AI) is playing a transformative role in stroke care, particularly in the diagnosis and management of acute ischemic stroke (AIS). The methodologies employed in these AI applications are diverse and sophisticated, leveraging various imaging modalities and AI networks to enhance diagnostic accuracy and treatment outcomes. AI algorithms are extensively used to analyze imaging data from non-contrast computed tomography (CT) and magnetic resonance imaging (MRI) to distinguish between ischemic and hemorrhagic strokes. These algorithms can identify critical features such as hypodensity on CT and hyperintensity on diffusion-weighted imaging (DWI) MRI, which are indicative of irreversibly damaged tissue. Additionally, AI models evaluate angiographic and perfusion imaging sequences to detect large vessel occlusions and assess the extent of ischemic penumbra, crucial for selecting patients for endovascular therapy [9].

In acute settings, AI-driven tools can rapidly process and interpret imaging data, providing real-time support to radiologists and neurologists. This is particularly important as timely intervention is critical in stroke management. AI applications can also predict short- and long-term functional outcomes by analyzing various clinical and imaging parameters. These models use machine learning techniques, including supervised learning with neural networks, to improve their accuracy and reliability over time. Several AI networks are employed in stroke diagnosis and treatment. Deep learning models, particularly convolutional neural networks (CNNs), are widely used for image analysis tasks such as segmentation and classification [25]. CNNs can automatically segment brain tissues and identify infarcted areas, reducing the time required for manual analysis [26]. Other machine learning techniques, such as support vector machines (SVMs) and random forests (RFs), are also used to classify stroke types and predict patient outcomes [27]. AI tools have been used to augment stroke management across prevention, prognostication, neuroimaging, diagnosis, treatment, and recovery. For instance, Vida Abedi et al. (2023) developed a framework for improving stroke diagnosis in emergency departments using deep learning. This framework utilized convolutional neural networks (CNNs) to analyze CT scans and identify stroke-related abnormalities with high accuracy [28]. Another study applied AI to ischemic stroke imaging for classification, segmentation, and image synthesis, demonstrating the potential of AI to enhance the precision of stroke diagnosis and treatment planning [10,29,30].

Commercially available AI platforms, such as the Brainomix e-Stroke system, use state-of-the-art AI algorithms to support doctors by providing real-time decision support in the interpretation of brain scans. These platforms offer fast and efficient analyses that optimize the delivery of stroke care, reducing turnaround times in the clinical workflow [31]. The Brainomix system, uses AI to assess the extent of ischemic damage and guide treatment decisions, ensuring that patients receive the most appropriate care promptly. Ongoing research continues to refine these AI methodologies and expand their applications. For example, studies are exploring the use of autoencoder architectures for deep learning, which can improve the classification of stroke patients into treatment-eligible groups based on the time since symptom onset [32]. AI models are being developed to integrate various data sources, including clinical records and imaging data, to assess stroke risk and outcomes [11] comprehensively. One notable study utilized a combination of CNNs and recurrent neural networks (RNNs) to analyze MRI and PET scans, achieving high accuracy in distinguishing between Alzheimer's patients and healthy controls [33]. Additionally, AI methods have been employed in drug discovery, identifying existing medications that may treat Alzheimer's and revealing new treatment targets [31]. For instance, a study used machine learning techniques to screen a large database of compounds, identifying several potential candidates for Alzheimer's treatment [34]. The economic impact of AI in healthcare is also significant, as it could alleviate the economic burden of neurodegenerative diseases like Alzheimer's. AI, including machine learning and deep learning, is widely applied in dementia research for diagnosis and progression detection. A study demonstrated the use of a deep learning model to predict the progression of Alzheimer's disease based on longitudinal clinical data, providing valuable insights for early intervention and treatment planning [23]

AI tools by using CNNs enable junior radiologists to match the performance of senior radiologists in identifying challenging aneurysms, particularly those smaller than 5mm [35]. The study emphasizes the role of AI in standardizing diagnostic quality across different centers, ensuring that all patients benefit from the highest diagnostic yield. Another research employed deep learning algorithms, specifically U-Net architectures, for the segmentation of aneurysms in MRA images. This approach achieved a high area under the curve (AUC) of 0.936, indicating excellent performance in distinguishing aneurysms from non-aneurysmal regions [36].

They used AI algorithms, including support vector machines (SVM) and random forests, which were evaluated for their effectiveness in detecting cerebral aneurysms using various imaging modalities such as CT, MRI, and digital subtraction angiography (DSA). The pooled sensitivity and specificity were 91.2% and 83.5%, respectively, showcasing the potential of AI in clinical settings [36]. Another study focused on the use of recurrent neural networks (RNNs) and long short-term memory networks (LSTMs) for predicting aneurysm rupture risk based on patient history and imaging data. These models provided valuable insights into rupture risk stratification, aiding in personalized treatment planning [21]. Cai et al [37] used artificial intelligence velocimetry (AIV) as a general platform to determine 3D flow fields and a microaneurysm-on-a-chip to simulate blood flow in microaneurysms in patients. They highlighted the integration of AI with fluid dynamics to predict aneurysm rupture by analyzing blood flow patterns. This novel approach combined physical laws with AI to infer pressures and stresses on aneurysm walls, offering a new dimension to rupture risk assessment. A study on the application of AI in automated morphologic analysis of aneurysms demonstrated that deep learning models could accurately measure aneurysm growth, assisting in monitoring and treatment planning [38].

BMC Medical Imaging; trained a CNN to identify subtle features that may be missed by human radiologists, leading to improved accuracy in early detection and diagnosis. The AI algorithms provide quantitative data on aneurysm characteristics, which is crucial for long-term monitoring and assessing the risk of rupture [23]. American Journal of Neuroradiology highlights the CNNs to enhance the precision of aneurysm detection such as subarachnoid hemorrhage. Thereby guiding clinical interventions more effectively [22]. AI has enabled real-time notifications during cerebral aneurysm procedures, enhancing the precision and safety of these interventions. For example, a study developed an AI-assisted system that provided real-time feedback to surgeons during aneurysm coiling procedures, significantly reducing the risk of complications [39]. AI is also used for the detection, risk assessment, prognosis, and recurrence prediction of intracranial aneurysms. A systematic review of AI techniques for aneurysm detection highlighted the superior performance of deep learning models, such as CNNs, in identifying aneurysms from medical images [24]. Radiomics, a field that combines radiology and AI, has been applied to intracranial aneurysms for precise diagnosis and treatment. A study utilized radiomic features extracted from CT angiography images to develop a predictive model for aneurysm rupture risk, demonstrating the potential of AI to improve clinical decision-making in aneurysm management [40]. Stroke segmentation, Aneurysm segmentation, and Alzheimer's detection by MRI images, as AI applications in brain disease are shown in Figure 2.

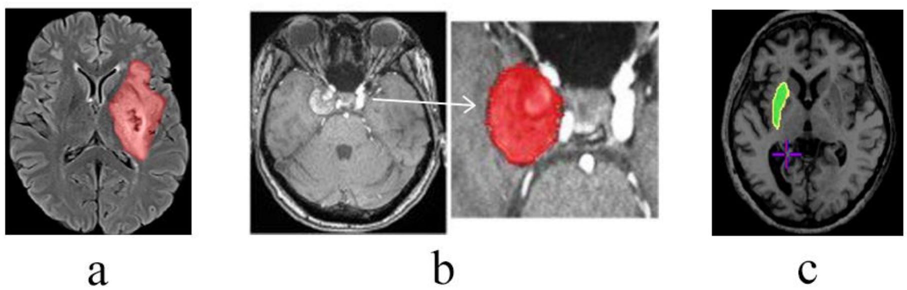

Figure 2. a) Stroke segmentation [41], b) Aneurysm segmentation, c) Alzheimer detection [42]

Results

Stroke Prediction and Segmentation

Several studies focus on improving the prediction and segmentation of stroke lesions using advanced machine-learning techniques. Hakim et al [43] utilized machine learning to predict infarct core from CT perfusion in acute ischemia, achieving significant accuracy improvements. Hatami et al [44] developed a CNN-LSTM model to fuse multimodal MRI and clinical data, enhancing the prediction of clinical outcomes in stroke patients. Gheibi et al [45] introduced CNN-Res, a deep learning framework for segmenting acute ischemic stroke lesions on multimodal MRI images, and demonstrated high precision in lesion detection. Zhi et al [46] explored machine-learning-based stroke prediction models, further advancing the field. Garcia-Salgado et al [47] used attention U-Net with generalized Dice focal loss for enhanced ischemic stroke lesion segmentation in MRI. Nazari-Farsani et al [48] predicted final ischemic stroke lesions from initial diffusion-weighted images using a deep neural network. Ye et al [49] developed an optimized ensemble deep-learning method for predicting acute ischemic stroke prognoses. These methods leverage neural networks to process complex medical imaging data, leading to more accurate and timely interventions for stroke patients.

Alzheimer's Disease Detection and Progression

In the realm of Alzheimer's disease, researchers have employed various machine learning models to enhance early detection and monitor disease progression. El-Assy et al [50] proposed a novel CNN architecture for detecting and classifying Alzheimer's disease using MRI data, showing promising results in early diagnosis. Basu et al [51] used variational autoencoders for early prediction of Alzheimer's disease progression, providing a robust framework for monitoring disease development. Castellano et al [52] combined 3D MRI and amyloid PET in a multi-modal approach to automate Alzheimer's disease detection, significantly improving diagnostic accuracy. Abuhantash et al [53] developed a comorbidity-based framework for Alzheimer's disease classification using graph neural networks. Bhattarai et al [54] utilized artificial intelligence to learn optimal regimen plans for Alzheimer's disease. Liu et al [55] applied deep Q-networks to learn dynamic treatment regimes from medical registry data. Morar et al [56] predicted cognitive test scores from variable-length multimodal data in Alzheimer's disease. Oh et al [57] extracted clinical phenotypes for Alzheimer's disease dementia from clinical notes using natural language processing. These advancements facilitate early intervention and personalized treatment plans, potentially slowing disease progression.

Aneurysm Detection and Risk Assessment

Deep learning models have shown considerable promise for aneurysm detection and risk assessment. Yang et al [58] developed a deep learning model for detecting cerebral aneurysms using CT angiography, achieving high sensitivity and specificity. Turhon et al [59] created a model to predict intracranial aneurysm rupture risk based on multi-omics factors, providing a comprehensive risk assessment tool. Raghuram et al [60] found that 3D aneurysm wall enhancement is associated with symptomatic presentation, aiding in the identification of high-risk aneurysms. Hachem et al [61] applied reinforcement learning for patient-specific optimal stenting of intracranial aneurysms. Yoon et al [62] discussed the development and performance evaluation of generative adversarial networks (GANs) for radiologists. Avesta et al [63] utilized 3D capsule networks for brain image segmentation. Zhou et al [64] employed ensemble deep learning for intracranial aneurysm detection from 3D vascular mesh models. These studies highlight the potential of machine learning in improving the accuracy and reliability of aneurysm detection and risk stratification, ultimately enhancing patient outcomes. The results are summarized in Table 1.

Table 1. AI applications in Stroke, Alzheimer and Aneurysm

No	Author(s)	Year	Topic	AI Method Used	Dataset Size-imaging method	Key Findings
1	Hakim, A.et al [43]	2021	Stroke	CNN	Large (ISLES)	High accuracy in identifying ischemic regions
2	Hatami, N. et al. [44]	2022	Stroke	Hybrid (CNN + LSTM)	Multimodal	Predict patient outcomes based on MRI and clinical data
3	Gheibi, Y. ea al. [45]	2023	Stroke	CNN-Res	Large (ISLES)	High accuracy in identifying ischemic regions
4	Zhi, S. et al. [46]	2024	Stroke	Support Vector Machine (SVM), Random Forest (RF), Gradient	2,346 stroke patients from the Chongqing University Central	Establish a stroke prediction model

				Boosting Machine (GBM)	Hospital	
5	Garcia-Salgado, B. P. et al. [47]	2024	Stroke	U-Net	MRI	High Dice similarity coefficients for stroke lesion segmentation
6	Nazari-Farsani, S. et al. [48]	2023	Stroke	3D CNN	PWI, DWI	High accuracy in predicting final lesion volumes and patient outcomes
7	Ye, W. et al. [49]	2023	Stroke	Optimized ensemble deep learning (OEDL)	Various	Improved prediction accuracy by AUC of 97.89%
8	El-Assy, A. M. et al. [50]	2024	Alzheimer	CNN	Large (ADNI), MRI	Achieved high accuracies in classifying different stages of Alzheimer's disease
9	Basu, S. et al. [51]	2019	Alzheimer	Variational Autoencoders (VAEs)	Structural MRI (sMRI)	Improved prediction of disease progression
10	Castellano, G. et al. [52]	2024	Alzheimer	Multimodal	MRI, PET, Clinical	Enhanced model performance
11	Abuhantash, F. et al. [53]	2024	Alzheimer	Graph Neural Networks (GNNs)	ADNI	Model complex relationships between data, high accuracy in predicting different stages of Alzheimer's disease.
12	Bhattarai, K. et al. [54]	2023	Alzheimer	Reinforcement learning (RL)	ADNI	Optimizing treatment strategies
13	Liu, N. et al. [55]	2019	Alzheimer	Deep Q-Network (DQN)	Patient-specific	Personalize treatment plans
14	Morar, U. et al. [56]	2023	Alzheimer	LSTM	MRI, PET, Cog, CSF	Predict the cognitive test scores of MMSE and ADAS-CoG13
15	Oh, I. et al. [57]	2023	Alzheimer	NLP	Clinical Notes	High accuracy in analyzing clinical notes and patient records
16	Yang, J. et al. [58]	2021	Aneurysms	CNN	CT Angiography	97.5%, High sensitivity and specificity in detecting intracranial aneurysms
17	Turhon, M. et al. [59]	2023	Aneurysms	Deep Learning	Imaging + Clinical	Predict aneurysm rupture risk
18	Raghuram, A. et al. [60]	2023	Aneurysms	3D Imaging	3T high-resolution MRI	Enhanced visualization and diagnostic accuracy
19	Hachem, E. et al. [61]	2023	Aneurysms	Reinforcement Learning	MRI, 3D-DSA	Predict the risk of intracranial aneurysm rupture and improve treatment outcomes.
20	Yoon, J. T. et al. [62]	2024	Aneurysms	GANs	Imaging Modality	Data augmentation, improved model performance
21	Avesta, A. et al. [63]	2023	Aneurysms	Capsule Network	MRI	Improved robustness to variations in imaging data
22	Zhou, M. et al. [64]	2024	Aneurysms	Transfer Learning	Large Datasets	Improves the detection accuracy of intracranial aneurysms

Across the reviewed studies, CNNs were the predominant model due to their effectiveness in image-based tasks such as segmentation and detection, while RNNs and LSTMs were employed for predictive modeling. The integration of multimodal data, including MRI, CT, PET, and clinical data, was a common strategy to improve model accuracy and robustness. The datasets varied significantly in size, with larger public datasets like ISLES, ATLAS, ADNI, OASIS, and ADSC being frequently used. “Aidoc”, “Avicenna.AI”, “Brainomix”, “RapidAI”, and “Viz.ai” are solutions that leverage artificial intelligence to enhance medical imaging, diagnosis, and treatment workflows, particularly in critical and time-sensitive conditions. These are designed to quickly detect and prioritize life-threatening conditions like ischemic strokes, pulmonary embolisms, intracranial and intracerebral hemorrhages, and other neurovascular diseases, thereby enabling timely intervention and treatment to help clinicians save time and cost of brain disease detection and treatment.

Conclusion

This review highlights the significant advancements in AI applications in brain diseases, particularly stroke, Alzheimer's disease, and aneurysms. The application of AI in the diagnosis and management of brain diseases, particularly stroke, Alzheimer's disease, and aneurysms has shown tremendous potential. AI-driven tools have improved diagnostic accuracy, facilitated early detection, efficient risk stratification, disease progress prediction, guided treatment decisions, and personalized treatment plans, leading to better patient outcomes. However, challenges related to data standardization, model interpretability, the need for real-time monitoring, clinical practice, and ethical considerations such as data privacy remain critical areas for further research.

Conflict of interest

The authors declared no conflict of interest.

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