Journal of Vocational Health Studies
https://e-journal.unair.ac.id/JVHS

THE ROLE OF ARTIFICIAL INTELLIGENCE (AI) ON MRI BRAIN EXAMINATION WITH CLINICAL ISCHEMIC STROKE

PERANAN ARTIFICIAL INTELLIGENCE (AI) PADA PEMERIKSAAN MRI BRAIN DENGAN KLINIS STROKE ISKEMIK

Literature Review
Studi Literatur

Oktaviani Aulia Rahma WMS [1*], Emi Murniati [2], Agustina Dwi Prastanti [2]

[1.] *Keluarga Sehat III Hospital, Semarang, Indonesia*
[2.] *Radiodiagnostic and Radiotherapy Technique Department, Health Polytechnic Ministry of Health Semarang, Indonesia*

A B S T R A C T

Background: *Application of Artificial Intelligence (AI) in radiology is named automatic image interpretation of neuroimaging stroke. It takes a short time to minimize the patient's brain damage.* ***Purpose:*** *Determine the role of AI in ischemic brain stroke MRI examination and find out the advantages and disadvantages of applying AI to ischemic brain stroke MRI examination.* ***Review:*** *It was a descriptive and qualitative study with a literature review approach. The selection of articles used the ScienceDirect, Scopus, ProQuest, PubMed, and Publish or Perish databases. The inclusion criteria included full articles, with the topic of AI on ischemic brain stroke MRI examinations published in the 2017 – 2022 range, articles published by English-language international journals with a classification of Q1 – Q3, and having DOI. Seven relevant pieces of article were obtained, then descriptive analysis was carried out by comparing and presenting the articles descriptively in tabular form.* ***Result:*** *The role of AI in MRI brain examination with clinical ischemic stroke, namely its role in automatic lesion segmentation, Time Since Stroke (TSS) classification, and infarct volume prediction. The advantages of AI included short image processing times and accurate results. The disadvantages of AI tended to decrease performance in small lesions, a large number of patients, limited data, and false positive results. The value of the Dice Score Coefficient (DSC) (0.53 – 0.86) was already high even though it had not reached 1 because it depended on the strength of the data used.* ***Conclusion:*** *The role of AI in MRI imaging of ischemic brain stroke helps in the diagnosis and prognosis of ischemic stroke patients. AI in stroke neuroimaging has advantages in time effectiveness and disadvantages in data limitations.*

A R T I C L E I N F O

Received 22 November 2022
Revised 24 January 2023
Accepted 30 May 2023
Available online 05 March 2024

Correspondence:
Oktaviani Aulia Rahma WMS

E-mail :
oktavianiauliarahma@gmail.com

Keywords:
Artificial intelligence, Brain ischemic stroke, MRI

A B S T R A K

Latar belakang: Penerapan *Artificial Intelligence* (AI) di bidang radiologi yaitu interpretasi citra otomatis *neuroimaging* stroke, diperlukan waktu singkat untuk meminimalisir kerusakan otak pasien. **Tujuan:** Mengetahui peranan AI pada pemeriksaan MRI *brain stroke* iskemik dan mengetahui kelebihan dan kekurangan penerapan AI pada pemeriksaan MRI *brain stroke* iskemik. **Telaah pustaka:** Jenis penelitian ini merupakan kualitatif deskriptif dengan pendekatan *literature review*. Pemilihan artikel menggunakan *database ScienceDirect*, *Scopus*, *ProQuest*, *PubMed*, dan *Publish or Perish*. Kriteria inklusi meliputi artikel utuh, dengan topik AI pada pemeriksaan MRI *brain stroke* iskemik yang dipublikasikan oleh jurnal internasional berbahasa inggris dengan klasifikasi Q1 – Q3 dan memiliki DOI dalam rentang 2017 – 2022. Didapatkan tujuh artikel relevan kemudian dilakukan analisis deskriptif dengan mengomparasi dan disajikan secara deskriptif dalam bentuk tabel. **Hasil:** Peranan AI pada pemeriksaan MRI brain dengan klinis stroke iskemik yaitu berperan dalam segmentasi lesi otomatis, klasifikasi *Time Since Stroke* (TSS), dan prediksi volume infark. Kelebihan AI yaitu waktu pemrosesan citra singkat dan hasil akurat. Kekurangan AI yaitu performa menurun pada lesi kecil, jumlah pasien besar, keterbatasan data dan menghasilkan *false positive*. Nilai *Dice Score Coefficient* (DSC) (0,53 – 0,86) sudah tinggi meskipun belum mencapai 1 karena bergantung pada kekuatan data yang digunakan. **Kesimpulan:** Peranan AI dalam pencitraan MRI *brain stroke* iskemik membantu diagnosis dan prognosis pasien stroke iskemik. AI dalam *neuroimaging* stroke memiliki kelebihan efektivitas waktu dan kekurangan dalam keterbatasan data.

Kata kunci:
Artificial intelligence,*Brain* stroke iskemik, MRI

Journal of Vocational Health Studies p-ISSN: 2580–7161; e-ISSN: 2580–717x
DOI: 10.20473/jvhs.V7.I3.2024.206-217

INTRODUCTION

The *Central Nervous System* (CNS) is one of the two main regulatory systems of the body besides the endocrine system. The CNS consists of the brain and spinal cord. The central nervous system functions to receive stimuli from external and internal bodies. The nerves in the CNS have three basic functional types of neurons, namely afferent neurons, efferent neurons, and interneurons forming complex interactive networks of excitable cells (Sherwood, 2016). The brain is one of the organs in the CNS. The brain consists of gray matter on the outside called the cortex and white matter on the inside. The parts of the brain are the cerebrum, cerebellum, and brain stem, which continues with the spinal cord. The cerebrum consists of two hemispheres with four lobes, namely the frontal lobe, parietal lobe, occipital lobe, and temporal lobe. While the cerebellum consists of two cerebral hemispheres. The brain stem consists of the mesencephalon, pons, and medulla oblongata (Long *et al*., 2016).

A stroke is a clinical event that occurs in the CNS organ, namely the brain. Stroke is a clinical syndrome characterized by focal or global cerebral dysfunction lasting 24 hours or more, which can lead to disability or death. Ischemic stroke is caused by blood vessels that are blocked by plaque (Budianto *et al*., 2020). The WHO states that every year 15 million people in the world suffer from a stroke. Five million of them died and another five million were permanently disabled. High blood pressure and tobacco use are risk factors for stroke (WHO, 2022). Data from Basic Health Research in 2018 stated that as many as 10.9 per 1000 Indonesians had a stroke. This figure decreased compared to 2013, which was 12.10 per 1000 population, and increased compared to 2007, which was 8.3 per 1000 population (Budianto *et al*., 2020). In stroke management, it is known as the golden period to provide fast and precise treatment. The golden period ranges from 3 – 4.5 hours, the longer the treatment, the more brain tissue is damaged (Arif *et al*., 2019).

The development of technology in radiology, it is hoped that radiographers can improve their skills to interact with new technologies. Besides that, service to patients remains the core of a radiographer's professionalism, so that the role of radiographers can develop to improve services in the field of medical imaging (Hardy and Harvey, 2020). The application of *Artificial Intelligence* (AI) with a variety of different techniques in brain *Magnetic Resonance Imaging* (MRI) examination with clinical ischemic stroke from several journal articles can provide additional information in ischemic stroke imaging.

Ischemic stroke is a neurological dysfunction caused by focal cerebral, spinal or retinal infarction. Ischemic stroke is characterized by a sudden loss of blood circulation in a part of the brain, and clinically causes loss of neurological function in that area. Acute ischemic stroke is caused by thrombosis or embolism in a cerebral artery, ischemic stroke is more common than hemorrhagic stroke (Budianto *et al*., 2020). Hemorrhagic stroke occurs in the brain which has ruptured blood vessels, so that blood pools in the cell tissue spaces in the brain. A hemorrhagic stroke usually begins with hypertension. Hypertension is the most important risk factor for hemorrhagic stroke in men and women (Setiawan, 2021).

Budianto *et al*. (2020) state that MRI is a supporting modality in stroke neuroradiology. The choice of MRI modality can provide details of normal brain structures and those with lesions, but it can also reveal cerebral edema early on. Meanwhile, hemorrhagic is easier to see through a CT scan (Runge *et al*., 2015). One of the MRI sequences, namely *Diffusion-Weighted Imaging* (DWI), has the highest sensitivity for detecting acute ischemia even though it is small and located in the posterior circulation (You *et al*., 2021). Mouridsen *et al*. (2020) state stroke management relies heavily on information obtained from imaging studies. An important thing that needs to be considered in stroke imaging is that it must be done quickly to get fast treatment and better results. In imaging, a stroke requires the presence of a radiologist and neurologist, but time is often limited. Therefore, an automatic method is needed in the evaluation of stroke imaging, one of which is through the image segmentation process with the help of a computer.

Leonard *et al*. (2018) stated the phrase AI was first used in a study thesis in 1955 regarding the use of computers to solve several types of problems provided to humans. AI is the activity aimed at making software intelligent and enabling an entity to function properly. AI is a constellation of technologies including machine learning, perception, reasoning, and natural language processing. It builds an intelligent software, which can do things that humans can do, and produce knowledge about the world that is needed, so that the knowledge can do useful things. Mueller and Massaron (2018) assert that there are four basic categories in the concept of AI, namely 1) Acting humanly when a computer acts like a human, for example in the Turing Test, which is a test that determines whether a machine is capable of exhibiting intelligent behavior similar to or indistinguishable from humans; 2) Thinking humanly, while computers think like humans, they perform tasks that require human intelligence to succeed, such as driving a car; 3) Thinking rationally, computers that think rationally rely on recorded behavior to provide guidance on how to interact with the environment based on the data at hand; the goal of this approach is to solve problems logically whenever possible; (d) Acting rationally, computers that act rationally rely on recorded actions to interact with the environment based on conditions, environmental factors, and existing data. Like thinking rationally, acting rationally in principle relies on solutions, which may not prove useful in practice. However, thinking rationally provides the basis on which the computer begins to be able to negotiate successful completion of objectives.

Machine learning is a modeling technique that engages data. The data in question include documents, audio, images, and others. Models are the end product of machine learning. Machine learning is very suitable for problems that involve intelligence, such as image and speech recognition, physical laws or mathematical equations fail to produce a model (Kim, 2017). Deep learning is a machine learning technique that uses deep neural networks. Deep neural network is a multi-layer neural network that contains two or more hidden layers. They lie in the end products of machine learning, and learning rules become techniques that generate models (deep neural networks) from data (training). Deep learning is here to overcome the previous neural network problems, namely the deeper the hidden layer, the more difficult it is to train and reduce its performance (Kim, 2017). *Convolutional Neural Network* (ConvNet) is a deep neural network specifically for image recognition. The technique exemplifies the importance of increasing the deep layer for processing information from images. Convolutional neural network is not only a deep neural network that has many hidden layers, but a deep neural network that is able to imitate how the brain's visual cortex processes and recognizes images (Kim, 2017).

Automated methods in the evaluation of stroke imaging can be assisted by the application of AI. AI applications can efficiently and accurately interpret neuroimaging results. AI is known as a unique field of study in computer science that allows the software to mimic human intelligence (Ding *et al*., 2020). Automated methods of evaluating stroke imaging can be assisted by the AI application. It can efficiently and accurately interpret neuroimaging results. In this case, AI is a branch of computer science that develops to imitate human intelligence. Its techniques have been widely applied in the management of ischemic stroke. In stroke imaging, AI focuses on the automatic diagnosis, automatic image segmentation and prediction of image results (Shafaat *et al*., 2021).

AI techniques have been widely applied in ischemic stroke management. In stroke imaging, AI focuses on the automatic diagnosis, automatic image segmentation, and prediction of image results (Shafaat *et al*., 2021). In a study conducted by Zhu *et al*. (2021) the application of machine learning techniques in classifying the time of onset helps determine patients who can be recommended thrombolytic therapy quickly, namely 0.8 seconds. In a study conducted by Chen et al. (2017), the application of the *Convolution Neural Network* (CNN) technique using DWI imagery can segment infarct lesions in less than one second. Lungren *et al*. (2019) argue that AI applications in radiology can be found in several fields, one of which is automatic image interpretation. These AI applications in automatic image interpretation require large amount of labeled data to achieve good performance. Image interpretation is more than just reading images, but collecting all patient information to reach the right diagnosis. AI has several limitations, one of which is bias. The AI model is as powerful as the data it receives as feedback. Particularly, the AI models are as powerful as the data they provide, and it is human who generate the data (Sultan, 2021) with the development of technology in radiology, it is hoped that radiographers can improve their skills to interact with new technologies. Besides that, service to patients remains the core of a radiographer's professionalism; hence, the role of radiographers can develop to improve services in the field of medical imaging (Hardy and Harvey 2020).

LITERATURE STUDY

This study is a descriptive qualitative study using the literature review method by collecting and analyzing data based on articles related to the AI application in MRI brain examination with clinical ischemic stroke. The study was carried out from February to May 2022. The database search for published international research articles included the keywords "Artificial Intelligence for MRI brain ischemic stroke", while the databases used were ScienceDirect, Scopus, ProQuest, PubMed, Publish or Perish. The articles were selected based on the inclusion and exclusion criteria that had been set.

Inclusion criteria

The articles included the ones published in the period 2017 to 2022. The research article was in full form, which included the title, author's name, year of publication, publisher, and abstract, as well as complete journal content and a bibliography. Articles from international journals were in English with a classification of Q1 – Q3 on Scimago and had DOI numbering.

Exclusion criteria

Articles compiled were on the topic of the role of AI in CT Scan examination of the brain with clinical ischemic stroke. In this case, the research articles used were not in full text, so the journal could not be fully accessed. The article uses a literature review research method.

RESULT

After identifying the problem, searching, and selecting articles, seven articles were obtained in which those articles matched the research topic and the criteria had been set. The stages of searching and selecting articles are presented in Figure 1. Based on the results of the search for articles in the database, the articles that met the inclusion criteria were obtained which are presented in Table 1.

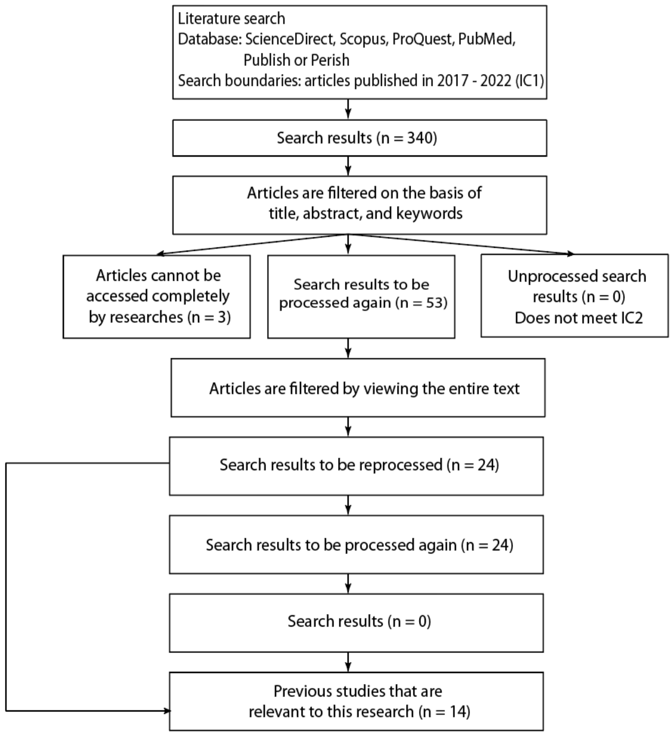

Figure 1. Article search flow

Table 1. List of articles

Title	Author, Year	Journal	Dataset
Fully automatic acute ischemic lesion segmentation in DWI using convolutional neural networks	Chen *et al*, 2017	Science Direct	Data were collected from 741 DWI images of acute stroke patients at local hospitals. 380 of them are used for CNN training and the remaining 361 are used for CNN testing.
Fully automatic segmentation of acute ischemic lesions on diffusion-weighted imaging using convolutional neural networks: comparison with conventional algorithms	Woo *et al*, 2019	Korean Journal of Radiology	Data were collected from 429 patients with symptoms of acute ischemic stroke who underwent MRI including DWI images for hyperacute to acute infarction, from September 2005 –August 2015.
A machine learning approach for classifying ischemic stroke onset time from imaging	Ho *et al*, 2019	IEEE Trans Med Imaging	DWI, PWI, FLAIR, ADC image data were collected from PACS University of California-Los Angeles in the period of December 2011 until December 2017 with a total of 181 patients, after applying inclusion criteria to 131 patients. Then reclassified according to TSS, 85 positive class (<4.5hrs) and 46 negative class (≥4.5hrs).
Use of deep learning to predict final ischemic stroke lesions from initial magnetic resonance imaging	Yu *et al*, 2020	JAMA Network	DWI and PWI image data were collected from *Imaging Collaterals in Acute Stroke* (iCAS) with a period of April 14th 2014 – April 15th 2018 and *Diffusion Weighted Imaging Evaluation for Understanding Stroke Evolution Study*-2 (DEFUSE-2) with a period of July 14th 2008 – 17th September 2011 with a total of 268 patients, after applying the inclusion criteria there were 182 patients.

The continuation of Table 1

Title	Author, Year	Journal	Dataset
An automatic machine learning approach for ischemic stroke onset time identification based on DWI and FLAIR imaging	Zhu *et al*, 2021	Science Direct	Data were collected from 268 *Acute Ischemic Stroke* (AIS) patients from January 2016 to December 2020. 180 cases from Nanjing First Hospital, Nanjing Medical University and 88 cases from Affiliated Jiangning Hospital of Nanjing Medical University. These patients were categorized into two classes according to TSS: negative (≤4.5 hours) and positive (>4.5 hours).
Prediction of Progression to Severe Stroke in Initially Diagnosed Anterior Circulation Ischemic Cerebral Infarction	Wei *et al*, 2021	Frontiers in Neurology	Data were collected from 1.237 patients diagnosed with *Acute-Subacute Anterior Circulation Nonlacuna Ischemic Infarction* (ASANCNLII) from Tongji Hospital, Shanghai, between 1st June 2017 – 31th August 2020. After applying the inclusion criteria, the total patients analyzed were 344, as many as 271 data for training and 73 data for testing.
Indirect volume estimation for acute ischemic stroke from diffusion weighted image using slice image segmentation	Lee *et al*, 2022	Journal of Personalized Medicine	DWI, PWI, FLAIR, ADC image data were collected from PACS University of California - Los Angeles in the period of December 2011 – December 2017 with a total of 181 patients, after applying inclusion criteria to 131 patients. Then reclassified according to TSS, 85 positive class (<4.5hrs) and 46 negative class (≥4.5hrs).
Prediction of tissue outcome and assessment of treatment effect in acute ischemic stroke using deep learning	Nielsen *et al*, 2018	AHA Journal	Data were collected from images of 222 patients with acute DWI, acute PWI, T2 FLAIR, including 187 patients who received intravenous rtPA.
Machine Learning Approach to Identify Stroke Within 4.5 Hours	Lee *et al*, 2020	AHA Journal	Data were collected from acute ischemic stroke patients at Asan Medical Center from January 2013 - February 2016. There were a total of 1830 patients and 355 patients analyzed.
Automatic post-stroke lesion segmentation on MR images using 3D residual convolutional neural network	Tomita N. *et al*, 2020	Elsevier	Data were collected from the *Anatomical Tracing of Lesions After Stroke* (ATLAS) dataset. In total, there were 304 MRI images and 239 images were analyzed.
Deep learning detection of penumbral tissue on arterial spin labeling in stroke	Wang *et al*, 2020	IEEE Trans Med	Data were collected from MRI acute ischemic stroke patients at the *University of California, Los Angeles* (UCLA) Medical Center from June 2010 to September 2013. The total data analyzed were 167 images.
Tissue outcome prediction in hyperacute ischemic stroke: comparison of machine learning models	Benzakoun *et al*, 2021	Journal of Cerebral Blood Flow & Metabolism	Data were collected from 2002 to 2019, 788 acute ischemic stroke patients were found, 394 of whom were analyzed.

The continuation of Table 1

Title	Author, Year	Journal	Dataset
Diagnosis and treatment effect of convolutional neural network-based magnetic resonance image features on severe stroke and mental state	Han *et al*, 2021	Hindawi	Data were collected from hospitals in the period of January 2017- October 2020. Data were obtained from 208 severe stroke patients.
Semantic segmentation guided detector for segmentation, classification, and lesion mapping of acute ischemic stroke in MRI images	Wei *et al*, 2022	Elsevier	Data were collected from Keelung Chang Gung Memorial Hospital in the 2017-2020 period, obtained 216 patients with 4606 slices.

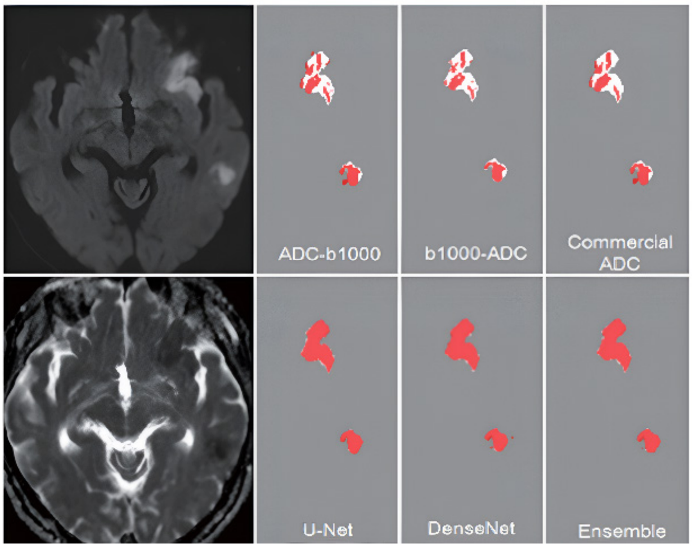

Figure 2. A 78-year-old woman with acute infarction of the left inferior frontal lobe and left temporal lobe. White ROI for ground truth, red ROI for the algorithm, pink for overlap area between ground truth and algorithm (Woo *et al*. 2019).

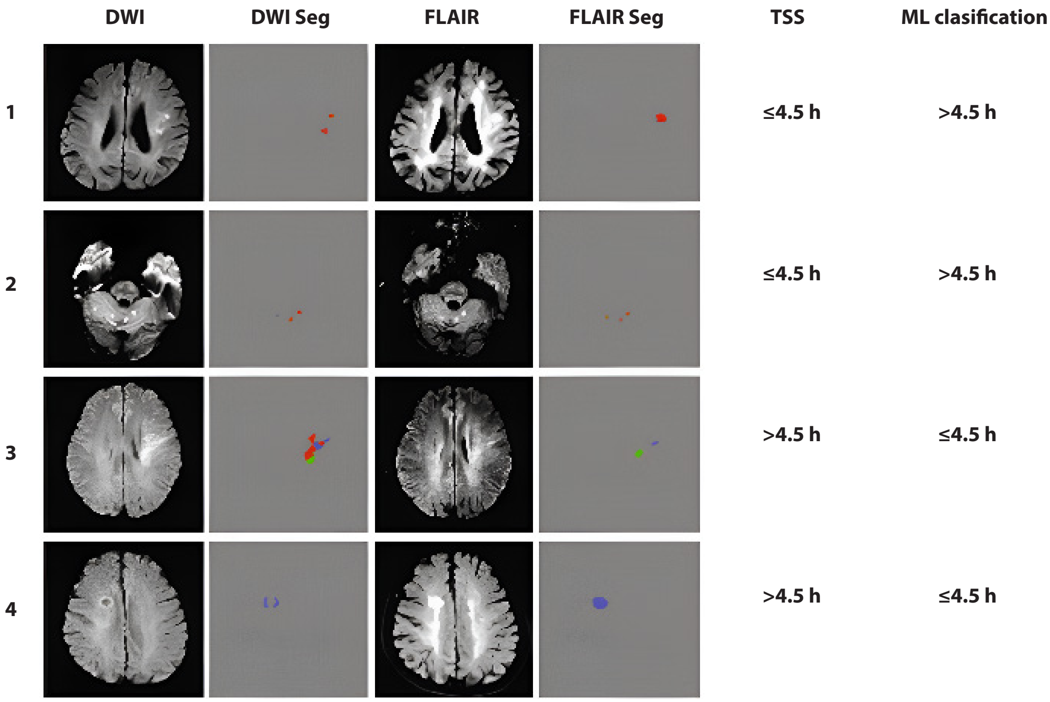

Figure 3. TSS classification uses machine learning. True positive pixels are represented by red, false positive pixels are represented by green, and false negative pixels are represented by blue (Zhu *et al*., 2021)

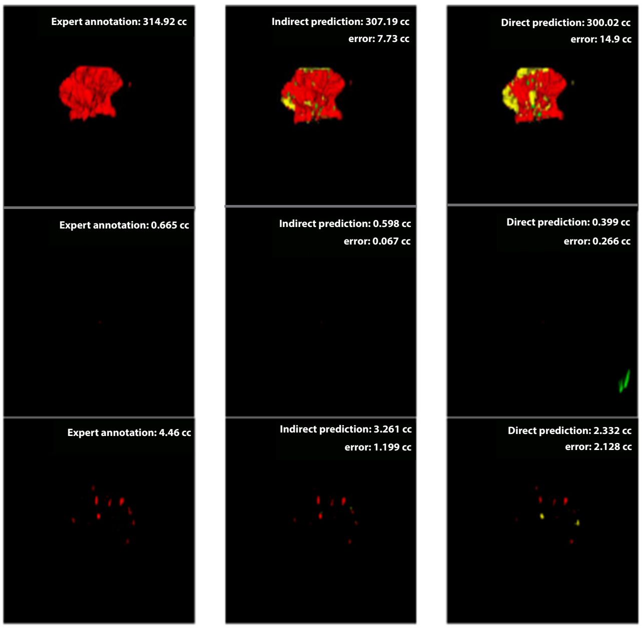

Figure 4. TSS classification uses machine learning. True positive pixels are represented by red, false positive pixels are represented by green, and false negative pixels are represented by blue (Zhu *et al.*, 2021)

The application of AI in MRI brain examination with clinical ischemic stroke is useful in automatic lesion segmentation (Figure 2). This is reinforced by research conducted by Chen *et al.* (2017), Woo *et al.* (2019), Tomita *et al.* (2020), Wang *et al.* (2020), Han *et al.* (2021), Zhu *et al.* (2021), Wei *et al.* (2021), Wei *et al.* (2022) and Lee *et al.* (2022). Furthermore, the image processing time is very short, making it more efficient.

Chen *et al.* (2017) asserted that processing a new DWI image took less than one second, while Woo *et al.* (2019) argued that it took 12 seconds to process one image slice, and Zhu *et al.* (2021) discovered that it took 1.5 seconds to process the image of each patient. The automatic lesion segmentation performed by AI is considered to have high accuracy. This is supported by the research of Chen *et al.* (2017) which stated that the dice score coefficient (0 ≤ DSC ≤ 1) obtained was 0.67. The study of Woo *et al.* (2019) obtained a DSC of 0.85. The research by Zhu *et al.* (2021) obtained DSC values of 0.803 for DWI images and 0.647 for FLAIR images. The research by Wei *et al.* (2021) obtained a DSC of 0.806 and Lee's study (2022) obtained an F1 score (0 ≤ F1 scores ≤ 1) 0.76 and 0.772. The F1 score was interpreted as the *Dice Score Coefficient* (DSC).

Another application of artificial intelligence (AI) in MRI brain examination with clinical ischemic stroke is in the classification of *Time Since Stroke (*TSS). This is reinforced by research conducted by Ho *et al.* (2019), Lee *et al.* (2020), and Zhu *et al.* (2021). Ho *et al.*(2019) stated that the TSS classification using AI was better than the DWI-FLAIR mismatch method carried out by Neuroradiologists, while Zhu *et al.* (2021) stated that TSS classification using AI required a very short time of 0.8 seconds for each patient. The accuracy of TSS classification using AI is also high as this is supported by the research of Ho *et al.* (2019) that obtained a DSC of 0.788, and the research by Zhu *et al.* (2021) that obtained a DSC of 0.805. According to the theory of Zhu *et al.* (2021), appropriate and rapid classification of TSS helps determine appropriate stroke treatment options, for example, thrombolytic therapy that can be done if the patient's TSS is <4.5 hours (Figure 3).

The next AI application in MRI brain examination with clinical ischemic stroke is the prediction of infarct volume (Figure 4). This is supported by the research conducted by Nielsen *et al.* (2018), Benzakoun *et al.* (2021), Yu *et al.* (2020), and Lee *et al.* (2022). In a study conducted by Yu *et al.* (2020), the accuracy of infarct volume prediction is quite high with a median DSC (DSC, (0 ≤ DSC ≤ 1)) of 0.53 (IQR (interquartile range), 0.31 – 0.68)), and obtained a volume error of 9 ml with IQR -14 – 29 ml, absolute volume error 24 ml with IQR 11 – 50 ml. While the research conducted by Lee *et al.* (2022) obtained F1 scores of 0.76 and 0.772, and obtained volume similarity (VS) of 93.3% and 89.2% respectively. According to the theory of Yu *et al.* (2020) and Lee *et al.* (2022), objective, accurate, and rapid prediction of infarct volume helps determine medical decisions and patient prognosis.

DISSCUSSION

Based on fourteen articles that have analyzed (Table 2 until Table 6). The advantages of AI in ischemic stroke neuroimaging, the fast process was agreed by Chen *et al*. (2017), Woo *et al*. (2019), and Zhu *et al*. (2021), with the fastest time required of 0.8 seconds and the longest 12 seconds for each new image. The accuracy produced by the AI model is also high, ranging from 0.53 to 0.86. According to Chen *et al*. (2017), the addition of MUSCLE Net can reduce the false positive value in the segmentation of stroke lesions generated by the AI model. Based on the research of Woo *et al*. (2019) combining two types of CNNs, namely U-Net and DenseNet, can increase the level of diagnostic accuracy in segmenting stroke lesions using an AI model. Meanwhile, based on the research by Lee *et al*. (2022), the indirect segmentation (2D) CNN model has more stable performance. Lastly,Ho *et al*. (2019) state that the *Logistic Regression* (LR) type machine learning model has an *Area Under Curve* (AUC) value of 0.765 in the TSS classification test.

Several articles reveal that AI in MRI brain examination with clinical ischemic stroke has several limitations. The research by Chen *et al*. (2017) and Yu *et al*. (2020) discovered that the performance of the AI model was influenced by the size of the lesion. Further, Chen *et al*. (2017) added that a decrease in performance occurred when the lesion segmentation was small. While Woo *et al*. (2019) argued that the performance of the AI model decreased with a large number of patients. Ho *et al*. (2019) stated that the performance of the AI model was low due to limited training data, while Wei *et al*. (2021) stated that data limitations made it difficult to generalize the results of the AI model. Zhu *et al*. (2021) and Lee *et al*.(2022) agree that the AI model produces false positives in which it will certainly cause errors in evaluating the performance results of the AI model. Based on the theory of Sultan (2021), the performance strength of the AI model is influenced by the strength of the data used during training. The stronger the data learned by the AI model, the less habitual there is. The point is that the more data and the quality of the data used during training, the better the AI will learn, so that the resulting AI output has high sensitivity and accuracy. This will certainly make the process of diagnosing ischemic stroke easier.

Table 2. Types of AI

Author	Types of AI
Chen *et al*. 2017	CNN
Woo *et al*. 2019	CNN
Ho *et al*. 2019	Machine learning
Yu *et al*. 2019	Deep learning
Zhu *et al*. 2021	Machine learning and CNN
Wei *et al*. 2021	CNN
Lee *et al*. 2022	CNN
Nielsen *et al*. 2018	Deep CNN
Lee *et al*. 2020	Machine learning
Tomita N. *et al*. 2020	3D residual CNN
Wang *et al*. 2020	Deep learning
Benzakoun *et al*. 2021	Machine learning
Han L. *et al*. 2021	CNN
Wei *et al*. 2022	Deep learning

Table 3. Role of AI

Author	Role of AI
Chen *et al*. 2017	Automatic image segmentation
Woo *et al*. 2019	Automatic image segmentation
Ho *et al*. 2019	TSS classification
Yu *et al*. 2020	Infarct lesion volume prediction
Zhu *et al*. 2021	TSS classification and infarct lesion segmentation
Wei *et al*. 2021	Automatic image segmentation
Lee *et al*. 2022	Segmentation and estimation of stroke lesion volume
Nielsen *et al*. 2018	Final lesion volume prediction
Lee *et al*. 2020	TSS classification
Tomita N. *et al*. 2020	Automatic post-stroke lesion segmentation
Wang *et al*. 2020	Automatic identify hypoperfusion lesion and penumbra in ASL images
Benzakoun *et al*. 2021	Prediction final infarct
Han L. *et al*. 2021	Image segmentation
Wei *et al*. 2022	Segmentation, classification, and map lesion distributions

Table 4. Benefits of AI

Author	Benefits of AI
Chen *et al*. 2017	The process of segmenting stroke lesions is faster and more accurate, with fewer false positives
Woo *et al*. 2019	The process of segmenting stroke lesions is faster and more accurate
Ho *et al*. 2019	The TSS classification process is better than the DWI-FLAIR mismatch method
Yu *et al*. 2020	Prediction of infarct lesion volume is comparable to or better than existing methods
Zhu *et al*. 2021	TSS classification process and image segmentation are faster and more accurate
Wei *et al*. 2021	Stroke lesion segmentation process produces high accuracy
Lee *et al*. 2022	The process of segmentation and estimation of stroke lesion volume is accurate and low computational cost
Nielsen *et al*. 2018	The CNN model is able to predict late infarction in acute ischemic stroke more accurately than the GLM model
Lee *et al*. 2020	The ML model is useful in identifying patients who are eligible for therapy among patients with an unclear stroke onset time
Tomita N. *et al*. 2020	3D segmentation applied to MRI imaging has been shown to be effective in volumetric segmentation of chronic ischemic stroke lesions
Wang *et al*. 2020	A promising method to assist decision-making for endovascular treatment in AIS patients
Benzakoun *et al*. 2021	The developed method looks promising for predicting final infarct and decision making
Han L. *et al*. 2021	Helps the clinical diagnosis and treatment of stroke and can effectively enhance the detection effect of brain domain characteristics
Wei *et al*. 2022	Segmentation process, classification is more practical

Table 5. Advantages of AI

Author	Advantages of AI
Chen *et al*. 2017	Segmentation of stroke lesions is faster (less than one second) and accurate (DSC value 0.67 and detection rate 0.94)
Woo *et al*. 2019	Segmentation of stroke lesions is faster (12 seconds) and accurate (DSC values 0.85 and 0.86)
Ho *et al*. 2019	TSS classification of patients is better than the DWI-FLAIR mismatch method (F1 score 0.788 and sensitivity 0.788)
Yu *et al*. 2020	Prediction of infarct lesion volume size is comparable or even better than existing methods (median DSC 0.53)
Zhu *et al*. 2021	TSS classification and image segmentation are fast (less than three seconds, 1.5 seconds for segmentation and 0.8 seconds for classification) and accurate (DWI segmentation DSC value 0.803 and FLAIR 0.647, TSS classification 0.805)
Wei *et al*. 2021	Segmentation of stroke lesions with high accuracy (DSC value 0.806)
Lee *et al*. 2022	Accurate segmentation and estimation of stroke lesion volume (76% and 77.2 F1-scores), low computational cost
Nielsen *et al*. 2018	The CNN model has the ability to learn and get better with every new patient
Lee *et al*. 2020	The AI model is more sensitive in identifying patients with stroke within the timeframe for acute thrombolysis
Tomita N. *et al*. 2020	To be a promising method in the future for volumetric segmentation of chronic stroke lesions using T1W MRI images
Wang *et al*. 2020	The AI model is able to predict the hypoperfusion region with high accuracy, sensitivity and specificity
Benzakoun *et al*. 2021	The developed AI model outperforms conventional methods
Han L. *et al*. 2021	The AI model can automatically classify stroke lesions with the smallest segmentation error and the highest segmentation accuracy
Wei *et al*. 2022	The AI model accurately categorizes and classifies the lesions in addition to being able to map lesions and calculate their placement in each brain region

Table 6. Disdvantages of AI

Author	Disadvantages of AI
Chen *et al*. 2017	Performance decreases when segmenting small lesions
Woo *et al*. 2019	Performance decreases in large number of patients
Ho *et al*. 2019	Low model performance due to limited data
Yu *et al*. 2020	The performance of the model is affected by the size of the lesion, the specificity is lower than the conventional method
Zhu *et al*. 2021	Produces false positives and false negatives, so that it is misclassified
Wei *et al*. 2021	Limited data, so it is difficult to generalize
Lee *et al*. 2022	3D segmentation performance is less stable, false positive is high
Nielsen *et al*. 2018	The performance of CNN type AI depends on the amount of training data used. If the training data is inadequate, CNN is prone to overfitting
Lee *et al*. 2020	AI models have not been sufficiently applied to clinical practice because the patient population is too small. Not yet able to analyze all groups of stroke patients
Tomita N. *et al*. 2020	Segmentation performance decreases in volume with small stroke lesions
Wang *et al*. 2020	The sensitivity is not as expected. Deep learning performance that needs to be improved by collecting larger training data
Benzakoun *et al*. 2021	AI model performance is less good on more heterogeneous data
Han L. *et al*. 2021	Too little data to train for the image segmentation algorithm
Wei *et al*. 2022	The training data used is limited, so the results obtained cannot be generalized

The role of AI is very useful for diagnosing ischemic stroke, but the decisions made by the AI model cannot be fully trusted. There is still a possibility that the results can be biased , for the AI model to be reliable, the role of the radiographer and radiologist is still needed in determining medical decisions related to clinical stroke. For example, an error in segmenting infarct lesions and classifying TSS will result in errors in determining appropriate patient care. The level of accuracy of the AI model is influenced by the DSC value, false positive, and false negative. The higher the DSC, the better the results obtained. Conversely, the higher the false positive and false negative, the more doubtful the results obtained.

CONCLUSION

The role of AI is useful in MRI brain examination with clinical ischemic stroke, namely its role in automatic lesion segmentation, the classification of TSS, and the prediction of infarct volume. The advantages of using AI in MRI brain examination with clinical ischemic stroke require a shorter time and a high level of accuracy. Disadvantages of using AI in brain MRI examination with clinical stroke are decreased performance in small lesions, a large number of patients, and limited data, resulting in false positives that result in misinterpretation. Decisions made by AI models cannot be trusted completely, still allowing the results obtained to be biased because they depend on the strength of the data learned by the AI model. The DSC, the AI model is already high (0.53 – 0.86) even though it has not reached 1. Thus, it is necessary to evaluate the results of the Radiologist to support the patient's medical decisions. In addition to helping in the diagnosis and prognosis of patients, the use of AI models can certainly help create a more effective and efficient radiology installation work ecosystem. Radiographers can start to apply AI to support the diagnostic management of MRI brain examination with clinical ischemic stroke, given its varied roles in establishing the diagnosis and prognosis of ischemic stroke.

The results of previous studies have shown that machine learning AI models play a role in the classification of TSS, CNN types play a role in automatic stroke lesion segmentation, and deep learning types play a role in infarct volume prediction. In the future, it is expected to conduct further research on the role of AI in MRI brain examination with clinical stroke in Indonesia using experimental methods or retrospective studies, because the application of AI in automatic image interpretation is influenced by data studied by AI and data tested by AI and is not yet available. It can be concluded that the collaboration between AI and radiology, especially in the interpretation of MRI images in clinical ischemic stroke, is an extraordinary collaboration, which can facilitate the process of diagnosing ischemic stroke. We discovered that ischemic stroke is a challenge for world health. It is hoped that with the development of this AI, we can pass the challenge perfectly. We hope that in the future there will be the development of AI in radiology for ischemic stroke in Indonesia because the results of AI detection are influenced by where the data studied come from. If there is a similarity between the data studied and analyzed, it will certainly produce high-quality output.

ACKNOWLEDGMENTS

We thank to Allah SWT for the guidance and support. Also, we express our gratitude for Director of Health Polytechnic Ministry of Health Semarang, Head of Radiodiagnostic and Radiotherapy Technique Department, and Head of Imaging Radiology Technology Bachelor Applied Program for their guidance and support. Lastly, our gratitude goes for our family for their guidance and support. The authors state there is no conflict of interest with the parties involved in this study.

REFERENCE

Arif, M., Okraini, N., Putra, A.Y.M., 2019. Hubungan Ketepatan 'GOLDEN PERIOD' dengan Derajat Kerusakan Neurologi pada Pasien Stroke Iskemik diruang Instalasi Gawat Darurat Rumah Sakit Stroke Nasional Bukit Tinggi Tahun 2018. Prosding Semin. Kesehat. Perintis Vol. 2(1), Pp. 94.

Benzakoun, J., Charron, S., Turc, G., Hassen, W. Ben, Legrand, L., Boulouis, G., Naggara, O., Baron, J.-C., Thirion, B., Oppenheim, C., 2021. Tissue Outcome Prediction in Hyperacute Ischemic Stroke: Comparison of Machine Learning Models. J. Cereb. Blood Flow Metab. Vol.41(11), Pp. 3085-3096.

Budianto, P., Mirawati, D.K., Prabaningtyas, H., Putra, S.E., 2021. Stroke Iskemik Akut: Dasar dan Klinis. UNS Press, Universitas Sebelas Maret.

Chen, L., Chen, L., Rueckert, D., 2017. Fully Automatic Acute Ischemic Lesion Segmentation in DWI using Convolutional Neural Networks. NeuroImage Clin. Vol. 15, Pp. 633-643.

Ding, L., Liu, C., Li, Z., Wang, Y., 2020. Incorporating Artificial Intelligence into Stroke Care and Research. Stroke Vol. 51(2), Pp. e351–e354.

Han, L., Liu, L., Hao, Y., Zhang, L., 2021. Diagnosis and Treatment Effect of Convolutional Neural Network-Based Magnetic Resonance Image Features on Severe Stroke and Mental State. Contrast Media Mol. Imaging Pp. 1-9.

Hardy, M., Harvey, H., 2020. Artificial Intelligence in Diagnostic Imaging: Impact on the Radiography Profession. Bristish J. Radiol. Vol. 93(11), Pp. 20190840.

Ho, K.C., Speier, W., Zhang, H., Fabien Scalzo, S.E.-S., Arnold, C.W., 2019. A Machine Learning Approach for Classifying Ischemic Stroke Onset Time from Imaging. IEEE Trans. Med. Imaging Vol. 38(7), PP. 1666-1676.

Kim, P., 2017. MATLAB Deep Learning Machine Learning, Neural Networks and Artificial Intelligence. Apress, Seoul, Soul-t'ukpyolsi, Korea (Republic of).

Lee, H., Lee, E.-J., Ham, S., Lee, H.-B., Lee, J.S., Kwon, S.U., Kim, J.S., Kim, N., Kang, D.-W., 2020. Machine Learning Approach to Identify Stroke within 4.5 Hours. Stroke Vol. 51(3), Pp. 860-866.

Lee, S.-A., Jang, J.-W., Park, S.-W., Kim, P.-J., Yeo, N.-Y., Kim, C., Kim, Y., Choi, H.-S., Kim, S., 2022. Indirect Volume Estimation for Acute Ischemic Stroke from Diffusion Weighted Image using Slice Image Segmentation. J. Pers. Med. Vol. 12(4), Pp. 521.

Leonard, Greg, Laurent Elder, Maroussia Levesque, Marshall Smith, Pascal Kropf, Sunisha Neupane, Aaron Martin, Raul Zambrano, and Cheryl Chan. 2018. Toward a Research Agenda Artificial Intelligence and Human Development.

Long, B.W., Rollins, J.H., Smith, B.J., 2022. Merrill's Atlas of Radiographic Positioning and Procedures, 13 th. ed. Elseiver.

Lungren, M.P.M.R.B.E., Ranschaert, E.R., Morozov, S., Algra., P.R., 2019. Artificial Intelligence in Medical Imaging. Cham Springer Nat. Switz. AG.

Mouridsen, K., Thurner, P., Zaharchuk, G., 2020. Artificial Intelligence Applications in Stroke. Stroke Vol. 51(8), Pp. 2573–2579.

Mueller, J.P., Massaron, L., 2023. Artificial Intelligence for Dummies. New Jersey: John Wiley & Sons.

Nielsen, A., Hansen, M.B., Tietze, A., Mouridsen, K., 2018. Prediction of Tissue Outcome and Assessment Of Treatment Effect in Acute Ischemic Stroke using Deep Learning. Stroke Vol. 49(6), PP. 1394-1401.

Runge, V.M., Heverhagen, J.T., 2022. Physics of Clinical MR Taught Through Images, 5 th. ed. Springer.

Setiawan, P.A., 2021. Diagnosis dan Tatalaksana Stroke Hemoragik. J. Med. Hutama Vol. 3(1), Pp.1660-1665.

Shafaat, O., Bernstock, J.D., Shafaat, A., Yedavalli, V.S., Elsayed, G., Gupta, S., Sotoudeh, E., Sair, H.I., Yousem, D.M., Sotoudeh, H., 2021. Leveraging Artificial Intelligence in Ischemic Stroke Imaging. J. Neuroradiol. Vol. 49(4), Pp. 343-351.

Sherwood, L., 2015. Human Physiology: from Cells to System, 9 th. ed. Cengage Learning, Canada.

Sultan, S., Saidi, S., 2021. Limitations of Artificial Intelligence. RIT Dubai.

Tomita, N., Jiang, S., Maeder, M.E., Hassanpour, S., 2020. Automatic Post-Stroke Lesion Segmentation on MR Images using 3D Residual Convolutional Neural Network. Neuroimage Clin. Vol. 27, Pp. 102276.

Wang, K., Shou, Q., Ma, S.J., Liebeskind, D., Qiao, X.J., Saver, J., Salamon, N., Kim, H., Yu, Y., Xie, Y., Zaharchuk, G., Scalzo, F., Wang, D.J.J., 2020. Deep Learning Detection of Penumbral Tissue on Arterial Spin Labelling in Stroke. Stroke Vol. 51(2), Pp. 489-497.

Wei, L., Cao, Y., Zhang, K., Xu, Y., Zhou, X., Meng, J., Shen, A., Ni, J., Yao, J., Shi, L., Zhang, Q., Wang, P., 2021. Prediction of Progression to Severe Stroke in Initially Diagnosed Anterior Circulation Ischemic Cerebral Infarction. Front. Neurol. Vol. 12, Pp. 652757.

Wei, Y.-C., Huang, W.-Y., Jian, C.-Y., Hsu, C.-C.H., Hsu, C.-C., Lin, C.-P., Cheng, C.-T., Chen, Y.-L., Wei, H.-Y., Chen, K.-F., 2022. Semantic Segmentation Guided Detector for Segmentation, Classification, and Lesion Mapping of Acute Ischemic Stroke in MRI Images. NeuroImage Clin. Vol. 35, Pp. 103044.

WHO, 2022. Stroke, Cerebrovascular Accident. WHO East. Mediterr. URL https://www.emro.who.int/health-topics/stroke-cerebrovascular-accident/index.html

Woo, I., Lee, A., Jung, S.C., Lee, H., Kim, N., Cho, S.J., Kim, D., Lee, J., Sunwoo, L., Kang, D.W., 2019. Fully Automatic Segmentation of Acute Ischemic Lesions on Diffusion-Weighted Imaging using Convolutional Neural Networks: Comparison with Conventional Algorithms. Korean J. Radiol. Vol. 20(8), Pp. 1275-1284.

You, S.-H., Kim, B., Kim, B.K., Park, S.E., 2021. Fast MRI in Acute Ischemic Stroke: Applications of MRI Acceleration Techniques for MR-Based Comprehensive Stroke Imaging. Investig. Magn. Reson. Imaging Vol. 25(2), Pp. 81-92.

Yu, Y., Xie, Y., Thamm, T., Gong, E., Ouyang, J., Huang, C., Christensen, S., Marks, M.P., Lansberg, M.G., Albers, G.W., Zaharchuk, G., 2020. Use of Deep Learning to Predict Final Ischemic Stroke Lesions from Initial Magnetic Resonance Imaging. JAMA Netw. Open Vol. 3(3), Pp. e200772.

Zhu, H., Jiang, L., Zhang, H., Luo, L., Chen, Yang, Chen, Yuchen, 2021. An Automatic Machine Learning Approach for Ischemic Stroke Onset Time Identification Based on DWI and FLAIR Imaging. NeuroImage Clin. Vol. 31, Pp. 102744.