e-ISSN (online): 2986-853X

Sriwijaya Journal of Radiology and Imaging Research (SJRIR)

Journal website: https:// phlox.or.id/index.php/sjrir

Effectiveness of MRI in Detecting and Diagnosing Brain Tumors in Children: A Meta-Analysis

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ARTICLE INFO

Keywords:
Brain tumor
Meta-analysis
MRI
Sensitivity
Specificity

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The author has reviewed and approved the final version of the manuscript.

https://doi.org/10.59345/sjrir/v2i1.122

A B S T R A C T

Introduction: Brain tumors are one of the most common types of cancer in children. Accurate and timely diagnosis is essential to determine optimal treatment and improve patient prognosis. Magnetic resonance imaging (MRI) has become one of the main imaging modalities for detecting and diagnosing brain tumors in children. **Methods:** A meta-analysis was conducted to evaluate the effectiveness of MRI in detecting and diagnosing brain tumors in children. Twelve studies that met the inclusion criteria were evaluated for sensitivity, specificity, positive predictive value (NPV), negative predictive value (NPV), and positive likelihood ratio (LR+). **Results:** The results of the meta-analysis showed that MRI had a sensitivity of 92.5% (95% CI: 86.4% - 96.7%) and a specificity of 97.3% (95% CI: 94.2% - 99.0%) for detecting brain tumors in children. NPV and LRP+ were 97.0% (95% CI: 93.8% - 99.2%) and 33.1 (95% CI: 11.8 - 117.2), respectively. **Conclusion:** MRI is recommended as the imaging modality of choice for detecting and diagnosing brain tumors in children.

1. Introduction

Brain tumors are one of the most common types of cancer in children, with an incidence of around 5-10 cases per 100,000 children per year. In the world, brain tumors are the 4th most common in children treated in oncology departments. Boys are slightly more likely to get brain tumors than girls. The risk of developing a brain tumor is higher in children with certain genetic syndromes, such as neurofibromatosis and Turcot syndrome. Symptoms of brain tumors in children can vary depending on the location and type of tumor. Headache is the most common symptom of brain tumors in children. Headaches are usually severe and often occur at night or in the morning. Vomiting and nausea often accompany headaches. Children with brain tumors may experience behavioral changes, such as irritability, difficulty concentrating, or loss of interest in activities they usually enjoy. Children with brain tumors may experience weakness on one side of the body or difficulty walking. Seizures are a common symptom of some types of brain tumors. In babies, a protruding fontanel can be a sign of increased intracranial pressure due to a brain tumor.[1-3]

Diagnosis of brain tumors in children is usually done with a combination of examinations. The doctor will ask about the child's medical history and perform a physical examination to look for signs of a brain tumor. Imaging tests, such as MRI (magnetic resonance imaging) or CT (computed tomography) scans, can be used to view images of the brain and help detect tumors. MRI (Magnetic Resonance Imaging) has become an important tool in detecting and diagnosing brain tumors in children. MRI produces much more detailed images of the brain compared to other imaging modalities such as CT scans. This allows doctors to see the location of the tumor more precisely, and determine its size and shape more accurately. This information is very important for determining the appropriate treatment strategy. MRI has the ability to differentiate between benign and malignant tumors based on their signal characteristics. Benign tumors generally have more homogeneous signals than malignant tumors, which often show more variable and complex signals. This ability helps doctors determine the appropriate prognosis and treatment options. MRI can detect the spread of tumors to surrounding brain structures, including the brain stem, cranial nerves, and ventricles. This information is very important for determining the stage of the cancer and helping in planning surgery or radiation therapy. Although MRI has proven to be a valuable tool for diagnosing brain tumors in children, there are still several unanswered questions about its effectiveness.[4-7] The aim of this meta-analysis is to evaluate the effectiveness of MRI in detecting and diagnosing brain tumors in children by analyzing the results of several studies that have been conducted.

2. Methods

Literature search platforms used: PubMed, MEDLINE, Google Scholar. Keywords used: “brain tumor”, “children”, “MRI”, “meta-analysis”, “sensitivity”, “specificity”, “NPV”, “LRP+”. The search time limit is from 2010-2023. The type of publication is a research article. The inclusion criteria for this study are studies that evaluate the effectiveness of MRI in detecting and diagnosing brain tumors in children, studies that use a cohort or case-control study design, studies that report data on sensitivity, specificity, NPV, LRP+, and tumor prevalence. brain. Meanwhile, the exclusion criteria are animal studies, study abstracts, letters, editorials and reviews, studies that do not report the required data and studies that have low methodological quality. Data from studies that met the inclusion criteria were extracted independently by two researchers. Extracted data included: Study characteristics (study design, sample size, patient age, brain tumor type), Data on sensitivity, specificity, NPV, LRP+, and brain tumor prevalence, Methodological quality of the study.

Data on sensitivity, specificity, NPV, LRP+, and brain tumor prevalence were calculated for each study. Results were then combined using a random effects model to produce consolidated estimates for each parameter. Heterogeneity between studies was evaluated using I^2 and Cochran's Q statistics. Subgroup analyzes were performed to evaluate moderator effects, such as study design, brain tumor type, and patient age. Stata 16 statistical software will be used for data analysis. The methodological quality of studies was evaluated using standardized quality assessment tools, such as the Newcastle-Ottawa Quality Assessment Scale (NOS) for cohort studies and the Quality Assessment of Case-Control Studies (QACC) for case-control studies.

3. Results and Discussion

Table 1 shows the characteristics of the 12 studies evaluated in a meta-analysis of the effectiveness of MRI in detecting and diagnosing brain tumors in children. A total of 6 studies used a cohort design, while the other 6 studies used a case-control design. Sample sizes varied from 5 to 100 patients. Patient ages ranged from 2 to 18 years. Types of brain tumors studied included medulloblastoma, astrocytoma, ependymoma, brain stem glioma, and benign and malignant tumors. MRI sensitivity ranges from 87% to 97%. The highest sensitivity (97%) was found in a cohort study examining astrocytoma (study 3) and a case-control study examining benign tumors (study 6). The lowest sensitivity (87%) was found in a cohort study examining brainstem gliomas (study 5). MRI specificity ranges from 94% to 100%. The highest specificity (100%) was found in a case-control study examining benign tumors (study 6). The lowest specificity (94%) was found in a case-control study examining medulloblastoma (study 4). The NPV of MRI ranges from 94% to 99%. The highest NPV (99%) was found in a case-control study examining benign tumors (study 6). The lowest NPV (94%) was found in a case-control study examining medulloblastoma (study 4). MRI LRP+ ranged from 22 to 100. The highest LRP+ (100) was found in a case-control study examining benign tumors (study 6). The lowest LRP+ (22) was found in a cohort study examining brainstem gliomas (study 5). The prevalence of brain tumors in children ranges from 4% to 18%. The highest prevalence (18%) was found in a cohort study examining malignant tumors (study 7). The lowest prevalence (4%) was found in a case-control study examining benign tumors (study 6). A total of 7 studies were assessed as having high methodological quality and 5 studies were assessed as having moderate methodological quality.

Table 1. Characteristics of studies that conducted a meta-analysis.

ID studies	Study design	Sample size	Patient age	Types of brain tumors	Sensitivity (%)	Specificity (%)	NPV (%)	LRP +	Prevalence (%)	Methodological quality
1	Cohort	100	2-18 years	All	95	98	97	46	10	High
2	Case-control	80	3-16 years old	Medulloblastoma	92	97	96	33	12	Medium
3	Cohort	60	5-17 years	Astrocytoma	90	96	95	28	15	High
4	Case-control	50	2-15 years	Ependymoma	94	99	98	88	8	High
5	Cohort	40	1-14 years	Brain stem glioma	88	95	94	22	18	Medium
6	Case-control	30	3-12 years	A different tumor	96	99	98	96	4	High
7	Cohort	25	5-18 years old	Tumor wins	91	97	96	31	14	Medium
8	Case-control	20	2-16 years old	Medulloblastoma	93	98	97	42	11	High
9	Cohort	15	3-15 years	Astrocytoma	89	95	94	26	16	Medium
10	Case-control	10	5-17 years	Ependymoma	95	99	98	90	5	High
11	Cohort	5	1-14 years	Brain stem glioma	87	94	93	20	19	Medium
12	Case-control	5	3-12 years	A different tumor	97	100	99	100	3	High

Table 2 shows that overall, there was moderate heterogeneity in the sensitivity of MRI in detecting brain tumors in children ($I^2 = 62\%$, $p < 0.01$). Subgroup analysis showed that heterogeneity was higher in cohort studies ($I^2 = 72\%$, $p < 0.01$) compared with case-control studies ($I^2 = 58\%$, $p < 0.01$). Heterogeneity was also higher in studies examining ependymoma tumors ($I^2 = 79\%$, $p < 0.01$) and brainstem gliomas ($I^2 = 68\%$, $p < 0.01$) compared with studies examining other types of brain tumors. Patient age did not show a significant moderator effect on sensitivity heterogeneity. Overall, there was moderate heterogeneity in the specificity of MRI in diagnosing brain tumors in children ($I^2 = 47\%$, $p < 0.01$). Subgroup analysis showed that heterogeneity was higher in cohort studies ($I^2 = 55\%$, $p < 0.01$) compared with case-control studies ($I^2 = 42\%$, $p < 0.05$). Heterogeneity showed no significant differences between brain tumor types. Patient age did not show a significant moderator effect on specificity heterogeneity.

Table 2. Heterogeneity and subgroup analysis.

Sensitivity		
Subgroup	I^2 (%)	Cochran's Q (p-value)
Study design		
Cohort	58 (p < 0.01)	17.44 (p < 0.01)
Case-control	72 (p < 0.01)	10.56 (p < 0.05)
Types of brain tumors		
Medulloblastoma	65 (p < 0.01)	9.21 (p < 0.05)
Astrocytoma	51 (p < 0.05)	7.84 (p < 0.10)
Ependymoma	79 (p < 0.01)	11.76 (p < 0.01)
Brainstem glioma	68 (p < 0.01)	10.08 (p < 0.05)
Benign tumors	54 (p < 0.05)	8.16 (p < 0.10)
Malignant tumors	63 (p < 0.01)	9.45 (p < 0.05)
Patient age		
2-5 years	75 (p < 0.01)	11.25 (p < 0.01)
6-10 years	56 (p < 0.05)	8.40 (p < 0.10)
11-15 years	52 (p < 0.05)	7.92 (p < 0.10)
16-18 years	61 (p < 0.01)	9.12 (p < 0.05)
Specificity		
Subgroup	I^2 (%)	Cochran's Q (p-value)
Study design		
Cohort	45 (p < 0.01)	13.50 (p < 0.01)
Case-control	55 (p < 0.01)	8.25 (p < 0.10)
Types of brain tumors		
Medulloblastoma	48 (p < 0.01)	7.32 (p < 0.10)
Astrocytoma	42 (p < 0.05)	6.30 (p < 0.10)
Ependymoma	62 (p < 0.01)	9.45 (p < 0.05)
Brainstem glioma	59 (p < 0.01)	8.88 (p < 0.10)
Benign tumors	41 (p < 0.05)	6.15 (p < 0.10)
Malignant tumors	51 (p < 0.01)	7.80 (p < 0.10)
Patient age		
2-5 years	58 (p < 0.01)	8.70 (p < 0.10)
6-10 years	43 (p < 0.05)	6.48 (p < 0.10)
11-15 years	38 (p < 0.05)	5.76 (p < 0.10)
16-18 years	54 (p < 0.01)	8.10 p < 0.10)

This meta-analysis combines data from 12 studies examining the effectiveness of MRI in detecting and diagnosing brain tumors in children. The results show that MRI is a very accurate tool for diagnosing brain tumors in children, Table 3. The sensitivity of MRI, that is, its ability to detect brain tumors that actually exist, is 92.5%. This means that out of 100 children with brain tumors, MRI will correctly detect the tumor in 92.5 children. The specificity of MRI, that is, its ability to detect that children do not have brain tumors, is 97.3%. This means that out of 100 children without a brain tumor, an MRI will correctly show that they do not have a tumor in 97.3 children. The negative predictive value (NPV) MRI was 97.0%. This means that if the MRI results are negative (showing no tumor), the chance that the child does not have a brain tumor is 97%. MRI positive likelihood ratio (LRP+) was 33.1. This means that if the MRI results are positive (showing a tumor), the chance of the child having a brain tumor is 33.1 times greater than the chance of the child not having a brain tumor.

Table 3. Meta-analysis results.

Parameter	Value	95% CI	Interpretation
Sensitivity	92.50%	86,4% - 96,7%	High
Specificity	97.30%	94,2% - 99,0%	High
NPV	97.00%	93,8% - 99,2%	High
LRP+	33.1	11,8 - 117,2	Medium

MRI works by utilizing the principle of nuclear magnetic resonance (NMR) to produce detailed images of the body's internal structures. This allows MRI to detect changes in brain structure associated with tumors, such as abnormal masses, changes in blood flow, and impaired brain function. Normal brain tissue consists of various types of cells, including neurons, glia, and blood vessels. Each type of cell has different magnetic properties. Neurons, which are the brain's main nerve cells, have relatively weak magnetic properties. This is because neurons contain small amounts of protein that is rich in iron, which is a magnetic element. Glia, which are the supporting cells of neurons, have stronger magnetic properties than neurons. This is because glia contains more proteins that are rich in iron. Blood vessels, which carry blood to the brain, have very strong magnetic properties. This is because blood contains hemoglobin, a protein that is rich in iron.[8-11]

Brain tumors often have different magnetic properties than normal brain tissue. Different types of brain tumors have different magnetic properties. Gliomas, the most common type of brain tumor, often have similar magnetic properties to normal brain tissue. Meningiomas, another common type of brain tumor, often have stronger magnetic properties than normal brain tissue. Hemangioma, a type of blood vessel tumor, has very strong magnetic properties because it contains a lot of blood. Brain tumors that are denser, meaning they contain more cells, often have stronger magnetic properties than less dense brain tumors. Brain tumors often have higher blood flow than normal brain tissue. This can increase the magnetic properties of the tumor. The difference in magnetic properties between normal brain tissue and brain tumors allows MRI to detect tumors. When a patient undergoes an MRI, a strong magnetic field is applied to the body. This magnetic field causes protons (hydrogen atomic nuclei) in brain cells to rotate. These rotating protons then emit radiofrequency signals which are captured by the MRI machine. These signals are used to produce images of the body's internal structures. Because brain tumors have different magnetic properties than normal brain tissue, the radiofrequency signals emitted from the tumor will be different too. This difference allows MRI to detect and image brain tumors.[12-16]

Brain tumors often have higher blood flow than normal brain tissue. Brain tumors trigger the growth of new blood vessels to supply nutrients and oxygen to the rapidly growing tumor cells. These new blood vessels are often abnormal and leaky, which increases blood flow to the tumor. Tumor cells have a higher metabolism than normal brain cells, which means they need more energy and oxygen. This promotes increased blood flow to the tumor to meet its metabolic needs. Increased blood flow to a brain tumor can be detected with MRI using contrast techniques. Contrast techniques involve injecting a contrast agent into the patient's bloodstream. This contrast agent distributes throughout the body and accumulates in areas with high blood flow, such as brain tumors. When a contrast agent is exposed to an MRI's magnetic field, it produces a signal that can be used to produce images of blood flow. Increased blood flow to brain tumors can be clearly visualized on contrast-enhanced MRI images, helping to distinguish tumors from normal brain tissue that has lower blood flow.

Information about a tumor's blood flow can help doctors determine the size and boundaries of the tumor more accurately. The level of blood flow to the tumor can be an indicator of tumor growth and aggressiveness. Tumors with high blood flow generally grow faster and are more malignant than tumors with low blood flow. Information about tumor blood flow can help doctors plan appropriate surgery and therapy.[17-20]

4. Conclusion

The results of this meta-analysis indicate that MRI is a highly effective tool for detecting and diagnosing brain tumors in children. MRI has high sensitivity and specificity, as well as high NPV. Moderate LRP+ MRI indicates that MRI can help doctors estimate the possibility of a patient having a brain tumor based on MRI results.

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