Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/10399
DOI URL: http://dx.doi.org/10.21474/IJAR01/10399

RESEARCH ARTICLE

ANALYSIS OF MRI UTILIZATION IN PEDIATRIC PATIENTS IN SAUDI ARABIA

Ali Alghamdi[1] and Majed Alahmari[2]

1. Department of Radiological Sciences, Faculty of Applied Medical Sciences, Tabuk University, Saudi Arabia.
2. Department of Radiology, King Fahad Specialist Hospital, Tabuk, Saudi Arabia.

Manuscript Info

Manuscript History
Received: 30 November 2019
Final Accepted: 31 December 2019
Published: January 2020

Key words:-
Pediatric, Magnetic Resonance Imaging, MRI Utilization, Clinical Indication

Abstract

Purpose: The aim of this study was to evaluate the Utilization of pediatric Magnetic Resonance Imaging (MRI) at a single public hospital.

Method: Ethical approval was obtained for data records of pediatric MRI scans from 1st January to 31st December 2018 to be extracted from the Radiology Information System (RIS) at the King Fahad Specialist Hospital (KFSH) in Tabuk City, Saudi Arabia. Usage rates were classified and analysed according to the major influencing factors, namely age, gender, admission type, exam type, indication and the use of contrast agents.The frequency variations of genders were evaluated, and the chi-square test was used to analyse whether there was an association between age and other categories such as admission and exam types.

Results: Overall, the study shows a pediatric MRI usage rate per MRI unit visit of 5.1%. Headache, back pain, pain and undescended testes were the most common indications in neuroradiology, spine, musculoskeletal and abdomen and pelvis exams, respectively. Among outpatients, more males had an MRI scan than females (49/77= 63.6 %, p= 0.169) while among inpatients, more females had an MRI scan than males (47/75= 62.7 % p= 0.728). Inpatients who had an MRI scan were significantly younger (mean age = 2.40, std = ± 4.1) than the outpatients (mean age = 6.6, std = ± 4.6) p = 0.000. There was a significant difference between the mean age of patients undergone brain MRI and different exam types as the mean age of brain was 3.3 ± 4.6, 7.4 ± 4.9 (p= 0.02) for spinal scans, 7.1 ± 3.9(p= 0.000) for musculoskeletal exams and 6.3 ± 5.2(p = 0.018) for abdomen and pelvis exams.

Conclusion: Pediatric MRI usage was significantly influenced by age, most notably between outpatients and inpatients and between exam types.

Introduction:-

The imaging accuracy produce by the advanced medical imaging technology made these procedures attractive diagnostic tools by physicians in all departments. In the radiology department, there are several imaging modalities that provide a variety of diagnostic features, and one of the most favourable imaging tools is the Computed

Corresponding Author:- Ali Alghamdi
Address:- Department of Radiological Sciences, Faculty of Applied Medical Sciences, Tabuk University, Saudi Arabia.

Tomography (CT) scan. A CT scan can rapidly diagnose many serious conditions and can provide valuable information regarding internal organs and vessels. However, the main disadvantage of CT scan is the relatively high radiation dose that a patient receives, which may increase the number of malignancies related to diagnostic imaging [1–3]. Despite this, approximately four million pediatric CT scans of the head, chest, abdomen, pelvis and spine are performed around the world annually, and are predicted to cause 4,870 future cancersfor an estimated 4 million patients[3]. Radiation from CT scanningis estimated to cause 0.7% of total expected baseline cancer incidents and 1% of cancer mortality [2]. Physicians, therefore, need to decide whether the risk of developing cancer as a result of radiation exposure outweighs the risks of not performing a CT scan at all.

Magnetic Resonance Imaging (MRI) is the most favourable alternative as it utilizes non-ionizingform of electromagnetic radiation. MRI is usually used for conditions that cannot be accurately assessed by other cheaper, faster imaging modalities such as plain-film x-rays, ultrasound and CT scanning. However, MRI has a much longer scanning time, which may increase the need to use anaesthesia in medically unstable patients. In addition, it is contraindicative in patients who have some types of metallic implants and who suffer from claustrophobia.

The use of pediatric MRI in radiology departments is poorly understood. Understanding the usage patterns and workflow of pediatric MRI would be a research area of great interest. The purpose of this study is to evaluate MRI usage for pediatric patients aged 13 years and under. Furthermore, based on the types of scans being performed, a radiologist can determine whether a pediatric patient needs an MRI scan, or whether they can be assessed by an alternative imaging modality.

Methods:-

Setting:

Ethical approval was obtained from the Institutional Review Board (IRB) committee at the University of Tabuk to conduct this retrospective study at single-site public hospital. The confidentiality of patients was ensured by saving all the relevant data on a computer that only the researcher had access to. In addition, all the patients taking part in the study were anonymised.

The MRI images collected using Optima 450w wide bore 1.5T MRI scanner, manufactured by GE Healthcare. Two scanners operate between 8 am and 5 pm and are used by the outpatient, inpatient and emergency departments. Thursdays are assigned for patients who usually need anaesthesia to remain still –such as patients who were less than two years old. Priority is usually given to patients referred from the emergency department or for urgent inpatient cases. The scanners stop operating at 5 pm and there are no night shifts required.

Outpatient MRI exams performed during this period are ordered by the pediatric department or referred from other hospitals. All requests are discussed with the radiologist on duty.

Data extraction:

Data from all pediatric MRI exams performed between January 2018 and January 2019 were obtained from RIS and were combined with demographic data.The total number of all MRI exams for all ages in the same period was also extracted for comparison. The data collected included age, gender, admission type, scan type, indication, and the use of contrast in order to find the extentof pediatric MRI Utilization.

The KFSH began operating in 2016 and has 500 beds. In addition to two other public hospitals, it serves a population of 800,000 in the North West province and surrounding areas. This study seeks to address the usage of pediatric MRI and to highlight whether it is being over- or underused. The purpose of our study was to evaluate the Utilization of MRIfor pediatric patients aged 13 years and under which are the ages that referred from pediatric clinic.

Results:-

There were 158 pediatric MRI exams performed on 121 patients aged 13 years and under (mean= 4.5 ± 4.8.) during the 12-month period (an average of 1.3 studies per patient). Five exams were excluded due to incomplete data meaning that 153 exams were analysed. The total number of MRI scans performed at the hospital over the 12-month period was 3,089, meaning that pediatric MRI exams accounted for 5.1% of the overall scans. For comparison, during the same time period, 2931 MRI exams were performed on patients older than 13years old.

There were a slightly higher number of MRI exams performed on males (51.0%, n= 78 exams) than females (49.0%, n= 75 exams).Of those patients, 75 (49%) were inpatients (see Table 1) and 77 (50.3%) were outpatients, with only one patient being referred from the emergency department (see Figure 1).

Table 1:- The distribution of male and female patients between admission type and procedures.

Gender				Procedure				Total
				Brain	Spine	Musculo-skeletal	Abdomen and Pelvis	
Male	Admission	Outpatient	Count	26	4	12	7	49
			% within admission	53.1%	8.2%	24.5%	14.3%	100.0%
			% within procedure	57.8%	100.0%	60.0%	87.5%	63.6%
			% of total	33.8%	5.2%	15.6%	9.1%	63.6%
		Inpatient	Count	19	0	8	1	28
			% within admission	67.9%	0.0%	28.6%	3.6%	100.0%
			% within procedure	42.2%	0.0%	40.0%	12.5%	36.4%
			% of total	24.7%	0.0%	10.4%	1.3%	36.4%
	Total		Count	45	4	20	8	77
			% within admission	58.4%	5.2%	26.0%	10.4%	100.0%
			% within procedure	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	58.4%	5.2%	26.0%	10.4%	100.0%
Female	Admission	Outpatient	Count	19	2	4	3	28
			% within admission	67.9%	7.1%	14.3%	10.7%	100.0%
			% within procedure	35.2%	66.7%	36.4%	42.9%	37.3%
			% of Total	25.3%	2.7%	5.3%	4.0%	37.3%
		Inpatient	Count	35	1	7	4	47
			% within admission	74.5%	2.1%	14.9%	8.5%	100.0%
			% within procedure	64.8%	33.3%	63.6%	57.1%	62.7%
			% of Total	46.7%	1.3%	9.3%	5.3%	62.7%
	Total		Count	54	3	11	7	75
			% within admission	72.0%	4.0%	14.7%	9.3%	100.0%
			% within procedure	100.0%	100.0%	100.0%	100.0%	100.0%
			% of Total	72.0%	4.0%	14.7%	9.3%	100.0%

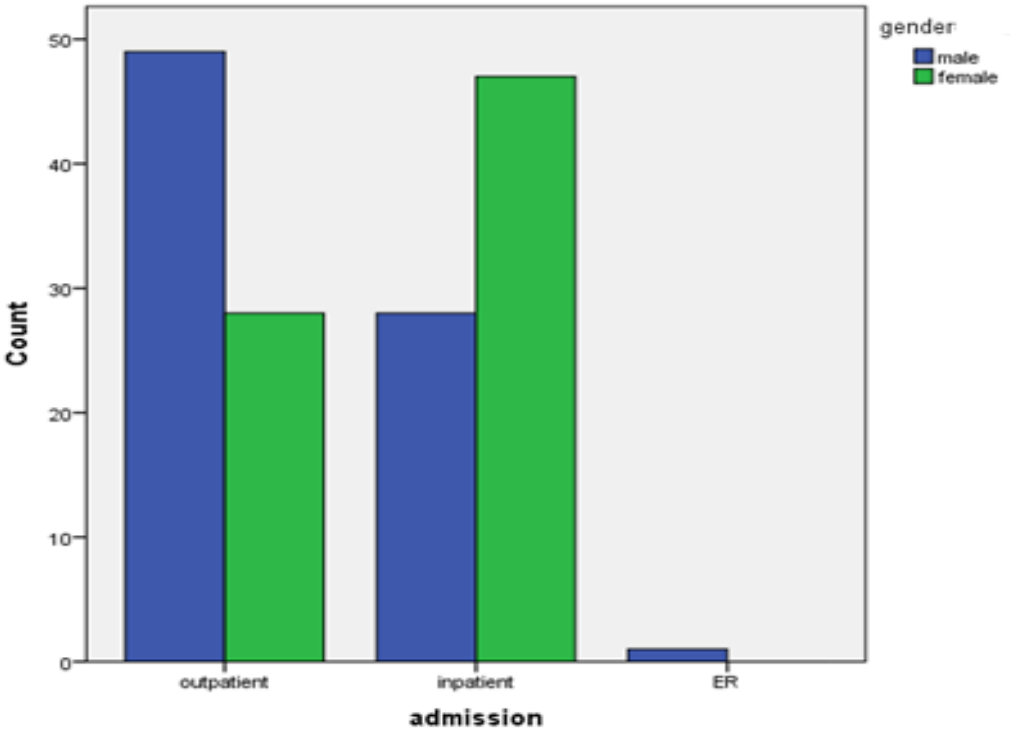

Figure 1:- The distribution of male and female exams between outpatients and inpatients.

The results showed that there were higher rates of female exams among inpatient (47/75= 62.7 %) and higher rates of male exams among outpatients (49/77= 63.6 %). In addition, 69.3% of the MRI exams were neuroradiological exams –of which 93.4% were of the brain and 6.6% were of the spine – 21.6% were musculoskeletal and 4.1% were of the chest, abdomen and/or pelvis. Additionally, 15.7% (n= 24) of the exams used contrast media (gadolinium)– of which 77.1% were brain, 22.9% were musculoskeletal (see Figure 2).

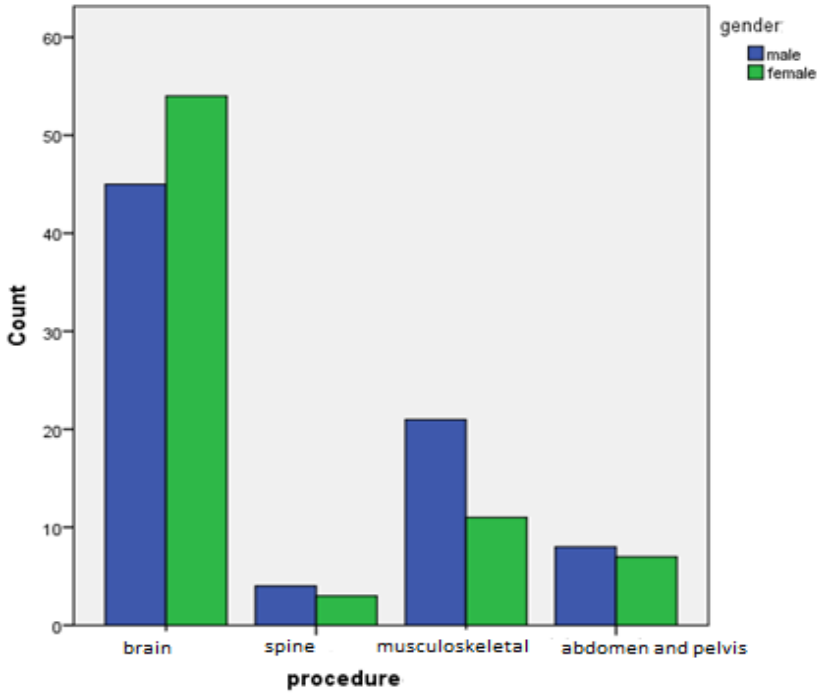

Figure 2:- The distribution of male and female patients between different exam types.

Within the inpatient group, the distribution of the procedure type is shown in Figure 3, where more females than males had brain, spine, abdomen and pelvis scans, while more musculoskeletal exams wereperformed on males.

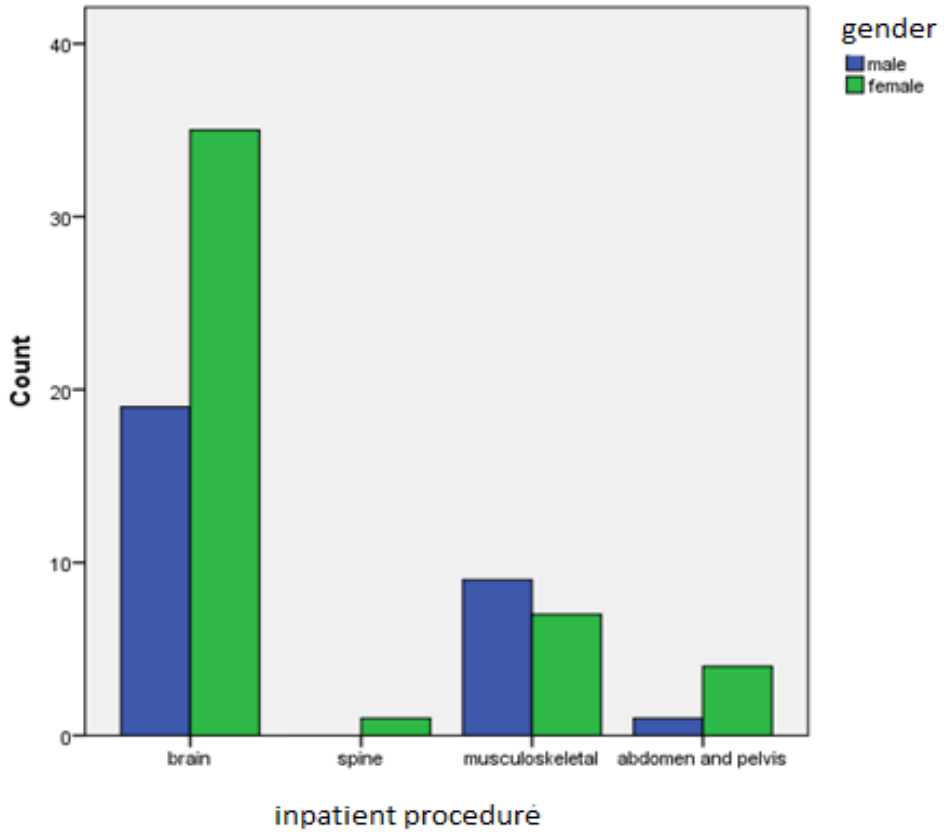

Figure 3:- The distribution of male and female patients between different exam types in the inpatient group.

However, within the outpatient group, more males than females were scanned for each procedure (Figure 4).

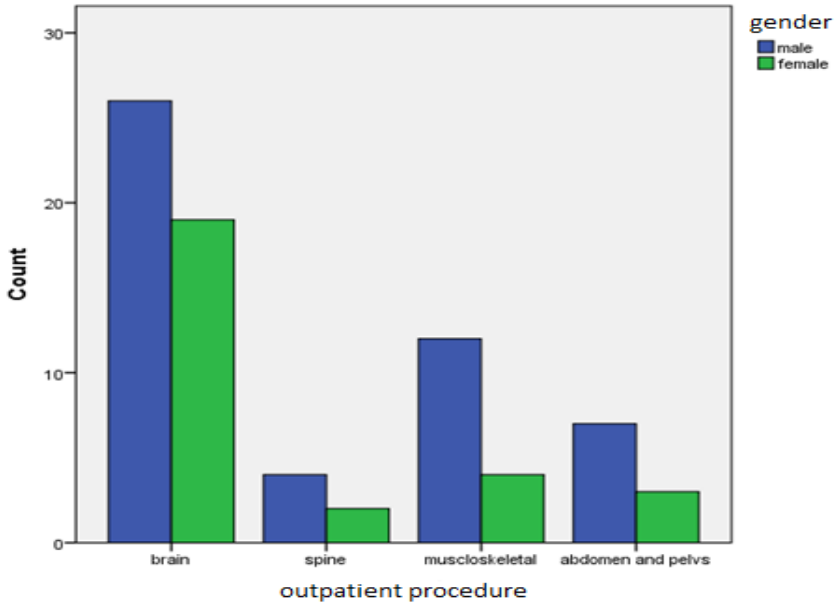

Figure 4:- The distribution of male and female patients between different exam types in the outpatient group.

For inpatient scans the female-to-male ratio was 1.6:1; for outpatient scans the male-to-female ratio was 1.7:1; for neuroradiology scans the female-to-male ratio was 1.8:1; for musculoskeletal scans the male-to-female ratio was 2:1; and for all chest, abdomen and/or pelvis scansthe male-to-female ratio was 1.3:1. In addition, for exams requiring the use of gadolinium, the ratio of male-to-female was 2.6:1.

The distribution of age categories is shown in Table 2, where the most populous group was those patients who were 2 years old orless (n= 74), which represented 48.4% of the total pediatric MRI patients. In contrast, the least populous group were those patients aged between 5 and 6, with only seven scans performed between them.Among those patients aged 2 years or less, 49 of the 74 patients were female and the other 25 were male (see Figure 5).

Table 2:- Number of patients in each age group.

Age		**Gender**		**Total**
		Male	**Female**	
0		16	34	50
	1	8	12	20
	2	5	1	6
	3	5	2	7
	4	6	2	8
	5	5	0	5
	6	1	1	2
	7	0	5	5
	8	4	3	7
	9	5	4	9
	10	3	3	6
	11	4	1	5
	12	5	4	9
	13	11	3	14
Total		78	75	153

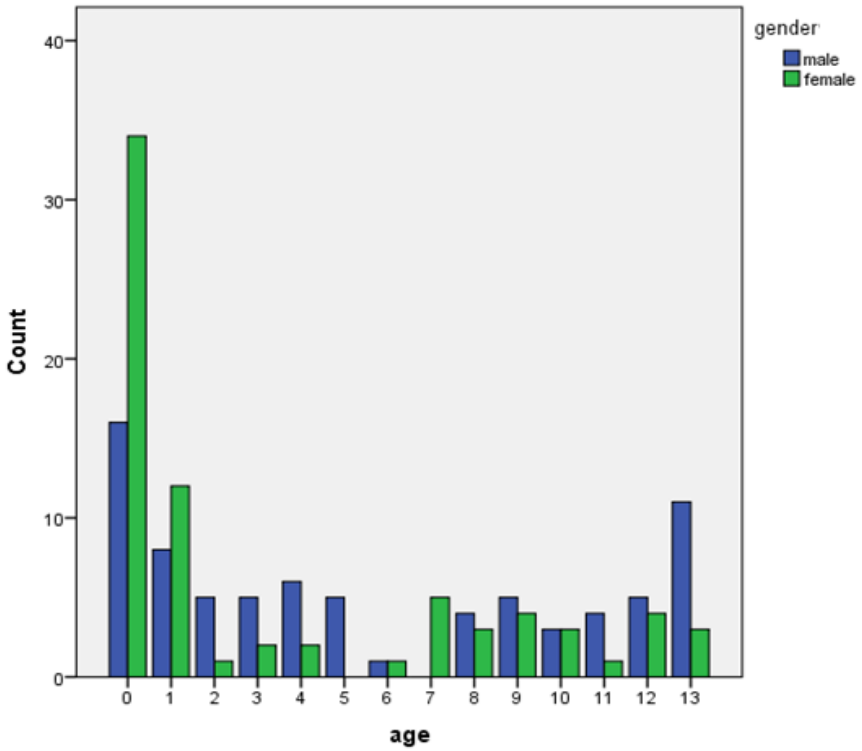

Figure 5: The distribution of patients among different age groups.

Table 3 shows the clinical indications for the exams and their frequencies. The most common indications for neuroradiology exams were headache, which accounted for 24.5% of all neurological exams, followed by Hypoxic Ischaemic Encephalopathy (HIE) with 17%. The most common indication for a spinal exam was back pain, which accounted for 25.1% of the scans. The most common indication for musculoskeletal scans was generalised pain, which accounted for 21.9% of all the musculoskeletal scans, while undescended testes were the most common indication for chest, abdomen and/or pelvis scans with 62.5%.

Table 3:- Clinical indications for pediatric MR imaging.

Neuroradiology	94
Headache	23
Seizure	12
Hypoxic Ischaemic Encephalopathy	16
Cortical atrophy	10
Hypertension	3
Optic Neuropathy (vision change)	1
Haematomas	4
Hearing loss	2
Numbness	2
Developmental delay	2
Other	19
Musculoskeletal	
Pain	7
Mass	2
Suspected osteomyelitis	8
Trauma	6
Bone Cyst	1
Swelling	1
Congenital Anomalies	1
Deformity	1
Suspected Arthritis	1
Other	4
Undescended Testes	4
Trauma	1
Mass	1
Spine	
Back pain	2
Numbness	1
Disc Prolapse	1
Other	4

Our results show that the inpatients who had MRI scans here were significantly younger (mean age = 2.40 std = ± 4.1) than the outpatients (mean age = 6.6, std = ± 4.6), where p = 0.000. The mean age in each exam type is shown in Table 3, where it can be seen that the average age of patients having brain scans is much less than those having abdomen and pelvis, musculoskeletal and spinal exams.

Table 4:- The mean age of different exam types, while the mean difference is significant at the 0.05 level.

	Age					
	N	Mean	Std. Deviation	95% Confidence Interval for Mean		p-value
				Lower Boundary	Upper Boundary	
Brain	99	3.27	4.589	2.36	4.19	

Spine	7	7.43	4.928	2.87	11.99	.000
Musculoskeletal	31	7.10	3.919	5.66	8.53	
Abdomen and Pelvis	15	6.27	5.161	3.41	9.12	
Total	152	4.54	4.820	3.77	5.31	

Discussion:-

In this study, we provided a report of how pediatric MRI is utilised in the radiology department of a single public hospital duringa 12-month period. A total of 69.3% of the exams were neuroradiology exams, which included the brain and spine. In previous reports, 98% of MRIs in the adult emergency department were neuroradiology exams [4], while 93% of the pediatric emergency MRI exams were also neuroradiological exams [5]. The higher rates of neuroradiological cases may be due to the fact that the cases from theemergency department are more urgent compared to the cases in our study, which mostly concerned outpatients and inpatients. However, there were lacks of pediatric MRI Utilization studies that compare inpatient and outpatient exams.

Our study shows a slightly higher overall rate of male patients (51.0%, n= 78 exams) compared to female patients (49.0%, n= 75 exams) who had an MRI scan. However, among inpatients, there were higher female patients than male. On the other hand, among outpatients, there was a higher ratio of males to females.The association between gender and type of admission was not well understood, and in order to provide more clarification, we analysed the association between gender and exam procedure within each admission type. Surprisingly, in outpatient exams, ratios of male MRI patients surpassed those of females in all the scan categories (neuroradiology, musculoskeletal and abdomen and pelvis scans). Within inpatient exams, on the other hand, the ratios of female scans were higher in all exam procedures except for musculoskeletal MRI. This raises the question as to whether female diseases are more critical than those of males, which require more care and therefore justify being admitted.

With regard to scan type, the overall pediatric MRI Utilization shows that there were higher ratios of male-to-female patients in spinal (1.3:2), musculoskeletal (2:1) and abdomen and pelvis exams (1.3:1). However, female ratios were higher than males in brain exams (1.2:1).

The reasons for the dominance of male ratios in all procedures except brain exams is still unknown; however, in contrast to the previous study where the neuroradiology exams were the largest contributor of the gender differences [6], musculoskeletal exams were the largest contributor to gender differences in our study.

We also analysed the association between gender and ratio of different categories and found that the female-to-male ratio was 1.6:1 for inpatient scans. For outpatient scans, the male-to-female ratio was 1.7:1; for neuroradiology scans, the female-to-male ratio was 1.8:1; for musculoskeletal scans, the male-to-female ratio was 2:1; and for all chest, abdomen and/or pelvis exams the male-to-female ratio was 1.3:1. For exams requiring the use of gadolinium, the male-to-female ratio was 2.6:1.

In our study, gadolinium contrast agents were used in 15.2% (n= 24) of the total cases. Although Gadolinium Based Contrast Agents (GBCAs) are considered to be a safe contrast agent, the FDA has recommended more studies to investigate the implications of GBCAs by conducting studies on GBCA Utilization in pediatric patients and to evaluate the agents and their doses in order to assist in the design of guidelines for the use of contrast indicated population [7].This is due to the fact that GBCAs remain in the body in measurable amounts in vital tissues such as the brain, despite the normal renal functions [8–10]. In addition, some studies reported that contrast can remain in bone tissue [11,12] and can be still be detected several years after administration [11]. Although no long-term adverse effects have yet been proven, GBCAs can nevertheless remain in small amounts in adults and children for years. Therefore, prudent adviceisto use GBCAs with caution [13].

In our study, musculoskeletal exams made up20.9% of the total sample. Although they were few in number overall, most of the musculoskeletal MRI exams were associated with male patients with a male-to-female ratio of 2:1.The most common indications weresuspected osteomyelitis followed by pain and trauma, respectively. In contrast, previous studies reported that the most common musculoskeletal indications in pediatric male patients were related to sports injuries [14] acute osteomyelitis and septic arthritis [15] as well as a greater prevalence of bone tumours[16].

Caetano et al. (2019) reported on the use of musculoskeletal MRI in children, and showed that MRI scans of the knee accounted for 35% of all the exams, followed by soft tissue trauma (13%), bone tumours (11%) and bone trauma (6.6%) [17].

Our study showed that only one patient was referred from the emergency room for an MRI scan.This may be due to the fact that the MRI scanners do not operate after working hours and could also be due to restrictions in the protocols of the radiology department that discourage emergency doctors from requesting MRI exams unless absolutely necessary. In addition, the CT scanner operates 24 hours a day and has the added advantage of having a rapid scan time, which allows for sedation-free scans and offers a fast and accurate alternative to MRI. Indeed, there are several factors that mean that MRI is notthe ideal modalityfor diagnosing emergency patients. These include a long waiting list, a long scan time, the possible need for sedation and the lack of staff outside of working hours. This was consistent with aprevious study performed in Saudi Arabia, where only 1.2% of all MRI exams for both adults and children were referred from the emergency department. Moreover, in another study, just 0.96% of all pediatric emergency patients had an MRI scan [18] and 0.51% in a further study of mixed adult and pediatric visits to the emergency department had an MRI scan[16].

MRI usage generally varies with age, where the highest rates were associated with patients aged < 1 year (31.6%, n=50) and 13 ≤years (8.8%, n= 14). This may be due to the need to reduce the exposure to ionising radiation for patients aged less than one year and due to other factors, such as 13-year old patients being more likely to be more stable, less claustrophobic and more likely to comply with instructions,while patients aged 6 tended to have the lowest number of scans (1.3%, n=2). This is in contrast to the date found in other studies, where the lowest number of scans was reported for those patients aged less than 3 years [17].

Brain MRI scans were significantly associated with youngest patients,with a mean age of 3.27 ± 4.6, while the highest mean ages were found in patients having spinal MRIs (mean age = 7.4 ± 4.9, p = 0.020) and musculoskeletal MRIs (mean age = 7.1 ± 3.9, p = 0.018). This may be explained by the fact that children become more active as they grow older, meaning that they are more likely to sustain a traumatic injury.

There was a significant difference between ages of inpatients (mean age = 2.4 ± 4.1) and outpatients (mean age = 6.6 ± 4.6), where p = 0.000, and where younger patients were admitted to hospital in higher numbers than older children. This is may be due to the fact that physical injuries such as the musculoskeletal and spinal traumas increases as the age of children increases which decreases the need for admission among older children. In this case other modalities such as x-ray and CT may provide adequate diagnosis for those patients and decrease the need for MRI. This was also related to the distribution of different age groups between different types of exams,as 99/153 (64.7%) of the total cases were for brain scans, with a mean age of 3.27 ± 4.6.

Limitations:-

1. The results of this study were limited to a single public hospital in Tabuk City, Saudi Arabia. Therefore, extending this study to several hospitals in different regions in Saudi Arabia is highly recommended in order to get a more generalized overview of the Saudi population.
2. The data were only collected over a12-months. In order to more accurately evaluate trends in pediatric MRI exams, several years' worth of data will need to be collected.
3. Although we reported clinical indications for each exam, we did not link these scans to other modalities, and we did not conduct follow-ups with any of the patients.
4. This study is limited by incomplete data on medical history and exams as well as the treatment outcomes.
5. The hospital protocols concerned with managing the MRI requests were not considered.

Conclusion:-

The vast majority of pediatric MRI investigations were neuroradiological and were performed on younger children. There was a significant difference in the mean ages of inpatients and outpatients in addition to the variations in the mean ages among different exam types. This study shows that the age of the patient is the factor that most significantly affects the Utilization of MRI in children.

References:-

1. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. N Engl J Med 2007;357:2277–2284.

2. Sodickson A, Baeyens PF, Andriole KP, Prevedello LM, Nawfel RD, Hanson R, et al. Recurrent CT, cumulative radiation exposure, and associated radiation-induced cancer risks from CT of adults. Radiology 2009;251:175–184.
3. Miglioretti DL, Johnson E, Williams A, Greenlee RT, Weinmann S, Solberg LI, et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated cancer risk. JAMA Pediatr 2013;167:700–707.
4. Rankey D, Leach JL, Leach SD. Emergency MRI utilization trends at a tertiary care academic medical center: baseline data. AcadRadiol 2008;15:438–443.
5. Ahn S, Kim WY, Lim KS, Ryoo SM, Sohn CH, Seo DW, et al. Advanced radiology utilization in a tertiary care emergency department from 2001 to 2010. PLoS One 2014;9:e112650.
6. Scheinfeld MH, Moon J-Y, Fagan MJ, Davoudzadeh R, Wang D, Taragin BH. MRI usage in a pediatric emergency department: an analysis of usage and usage trends over 5 years. PediatrRadiol 2017;47:327–332.
7. Roberts DR, Chatterjee AR. The Critical Need for Pediatric and Juvenile Animal Research Addressing Gadolinium Retention in the Developing Body. Invest Radiol 2019;54:72–75.
8. Kanda T, Ishii K, Kawaguchi H, Kitajima K, Takenaka D. High signal intensity in the dentate nucleus and globuspallidus on unenhanced T1-weighted MR images: relationship with increasing cumulative dose of a gadolinium-based contrast material. Radiology 2013;270:834–841.
9. McDonald RJ, McDonald JS, Kallmes DF, Jentoft ME, Murray DL, Thielen KR, et al. Intracranial gadolinium deposition after contrast-enhanced MR imaging. Radiology 2015;275:772–782.
10. Errante Y, Cirimele V, Mallio CA, Di Lazzaro V, Zobel BB, Quattrocchi CC. Progressive increase of T1 signal intensity of the dentate nucleus on unenhanced magnetic resonance images is associated with cumulative doses of intravenously administered gadodiamide in patients with normal renal function, suggesting dechelation. Invest Radiol 2014;49:685–690.
11. Darrah TH, Prutsman-Pfeiffer JJ, Poreda RJ, Campbell ME, Hauschka PV, Hannigan RE. Incorporation of excess gadolinium into human bone from medical contrast agents.Metallomics 2009;1:479–488.
12. comparison of gddtpa-bma (ominiscan) versus gd hp... - Google Scholar n.d. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=comparison+of+gd+dtpa-bma+%28ominiscan%29+versus+gd+hp+do3+%28orohance%29&btnG= (accessed February 4, 2020).
13. Blumfield E, Swenson DW, Iyer RS, Stanescu AL. Gadolinium-based contrast agents—review of recent literature on magnetic resonance imaging signal intensity changes and tissue deposits, with emphasis on pediatric patients. PediatrRadiol 2019;49:448–457.
14. Linakis JG, Amanullah S, Mello MJ. Emergency department visits for injury in school-aged children in the United States: a comparison of nonfatal injuries occurring within and outside of the school environment. AcadEmerg Med 2006;13:567–570.
15. Goergens ED, McEvoy A, Watson M, Barrett IR. Acute osteomyelitis and septic arthritis in children. J Paediatr Child Health 2005;41:59–62.
16. Niu X, Xu H, Inwards CY, Li Y, Ding Y, Letson GD, et al. Primary bone tumors: epidemiologic comparison of 9200 patients treated at Beijing JiShui Tan hospital, Beijing, China, with 10 165 patients at Mayo Clinic, Rochester, Minnesota. Arch Pathol Lab Med 2015;139:1149–1155.
17. Caetano AP, Alves P, Mendes P, Soares E. Magnetic resonance imaging of the musculoskeletal system in the pediatric population-a university hospital experience n.d.
18. Ramirez J, Thundiyil J, Cramm-Morgan KJ, Papa L, Dobleman C, Giordano P. 53: MRI utilization trends in a large tertiary care pediatric emergency department. Ann Emerg Med 2010;56:S18–S19.