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Surgical results in cases of osteoid osteoma: a single-center retrospective study

Şafak Aydın Şimşek[1], Tolgahan Cengiz[2], Ercan Bayar[1], Furkan Erdoğan[1], İsmail Büyükceran[1], Hüseyin Sina Coskun[1], Nevzat Dabak[1]

[1)] *Department of Orthopedics and Traumatology, Faculty of Medicine, Ondokuz Mayıs University, Samsun, Turkiye*
[2)] *Department of Orthopedics and Traumatology, İnebolu State Hospital, Kastamonu,Turkiye*
[3)] *Department of Orthopedics and Traumatology, Amasya Sabuncuoğlu Şerefeddin Training and Research Hospital, Amasya, Turkiye*

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Corresponding Author: Şafak Aydın Şimşek, drsafakaydin@gmail.com

ABSTRACT

Aims: Osteoid osteoma is a benign bone tumor with night pain that is initially responsive to salicylates and is characterized by new bone formation. However, it may not always present with typical findings. This study aims to evaluate the clinical, radiological, and histological findings of patients who were treated for osteoid osteoma and discusses the diagnostic stages and surgical results of patients treated for osteoid osteoma.

Methods: A retrospective examination was made of patients treated in the Orthopedics and Traumatology Clinic of the 3rd Step University Hospital and diagnosed with osteoid osteoma between January 2010 and January 2023. The patients' demographic data and clinical, radiological, and histopathological evaluations were recorded.

Results: In the surgical treatment in this study, the nidus was excised with the en-bloc resection method or burr-down-assisted intralesional curettage. In cases where the nidus was completely excised, it was observed that the initial complaints of the patients disappeared completely. In cases where the nidus could not be completely removed, a second surgery was planned, the nidus was removed and the patients' complaints were resolved.

Conclusion: Osteoid osteoma treatment must completely remove the nidus. Treatment options are evaluated according to the anatomical localization of the lesion. Burr-down assisted intralesional curettage is the main treatment principle in cases where the localization is clearly selected by measuring preoperative CT sections.

Keywords: Bone neoplasms, osteoma, osteoid, curettage, treatment outcome

INTRODUCTION

Osteoid osteoma (OO) is a benign, solitary bone lesion of osteoblast origin characterized by bone production. Henry Jaffe made the first definition related to osteoid osteoma in 1935,[1] and currently, osteoid osteoma constitutes approximately 15% of all bone lesions. OO is formed by a nidus formed from osteoids, osteoblasts, and fibrovascular stroma, is an average of 1cm in diameter, the center is radiolucent, and the edges have a sclerotic appearance.[2] This lesion, which is determined most often in males between the ages of 5 and 25 years, is located in the diaphysis and metaphysis of the long bones.[3] In approximately 30% of cases, a lesion is seen in the femur, tibia, spine, pelvis, and smaller carpal and tarsal bones.[2]

Clinically, the most typical symptom is severe pain to wake the patient from sleep at night. This pain responds dramatically to salicylates and non-steroid anti-inflammatory drugs (NSAID). Other than this typical pain, patients may present with different symptoms depending on the localization. For example, when there is superficial localization, findings such as pain on palpation, impaired gait, and muscle atrophy may be seen. In addition to the clinical findings in the diagnosis, the nidus should be shown with radiological imaging. Just as OO can be left for conservative follow-up, there are treatment options of open surgery and computed tomography (CT) -assisted radiofrequency ablation (RFA) procedure.

This study aimed to examine the demographic characteristics, clinical complaints, diagnostic methods, and treatment results of patients who applied surgical treatment to diagnose osteoid osteoma and compare these with literature data.

METHODS

The study included 38 patients with clinical, radiological, and histological findings consistent with osteoid osteoma who were operated on in the orthopedics and traumatology department of medical faculty hospital between January 2010

and January 2023. Patients who did not attend follow-up appointments regularly had incomplete data in the records and were treated with the radiofrequency ablation method, so they were excluded from the study.

Ondokuz Mayıs University Clinical Research Ethics Committee obtained the ethics committee approval with decision no: 2022/258, dated: 27.07.2022. We obtained informed consent forms from all patients for the procedure. The ethical rules and the principles of the Declaration of Helsinki carried out all procedures.

The patient's demographic data and preoperative and postoperative clinical and radiological findings were recorded retrospectively. The patients were evaluated in terms of age, gender, localization of the lesion, complaints on presentation, duration of complaints, and response to oral salicylates and NSAIDs. From the tests applied to the patients, the findings on the plain radiograph (x-rays), computed tomography (CT), magnetic resonance imaging (MRI), and bone scintigraphy were analyzed statistically.

The diagnosis is based on thin-section computerized tomography since misdiagnoses may occur when interpreting the usual tomography sections. The surgical treatment applied to all the patients was en-bloc resection or intralesional curettage with burr-down assistance, and the senior surgeon performed all of the procedures. According to computerized tomography sections, no adjuvant therapy is used following the en-bloc resection since it's a benign bone tumour. Preoperatively, the distance of the lesion is measured according to anatomical landmarks in CT axial, sagittal, and coronal sections. The skin incision is determined with the help of fluoroscopy according to the evaluation of CT measurements.

RESULTS

The evaluation was made of 38 patients operated on for a diagnosis of osteoid osteoma, comprising 20 (52.6%) males and 18 (47.4%) females, with a mean age of 12.5 years (range, 3-36 years). Involvement was seen on the right side in 21 (55.3%) patients and on the left in 17 (44.7%) (Table 1). The most common sites of localization of the lesion were the femur (n.14, 36.8%) and the tibia-fibula (n:9, 23.7%), followed by bones of the hand in 5 (13.1%), bones of the foot in 3 (7.9%), the pelvic bones in 3 (7.9%), the humerus in 2 (5.3%), and the radius in 2 (5.3%). Of the cases with the lesion in the hand, it was in a phalanx in 4 and the os triquetrum in 1. The lesion was in a phalanx in the cases with foot region involvement (Table 2). When asked about the character of the pain, 25 (65.8%) patients described typical pain of osteoid osteoma

Table 1. Demographic data of the patients

Categories	n=38	%
Age (Mean on year)	12,5	
Sex (number of patients)		
Male	20	52.6%
Female	18	47.4%
Admission complaints		
Aspecific pain	5	13.2%
Pain that wakes the patient from sleep at night	25	65.7%
Other complaints	8	21.1%
Responded to oral salicylates and NSAIDs	29	76.3%
Laterality (number of patients)		
Right	21	55.3%
Left	17	44.7%

Table 2. Anatomical localization of 38 patients with osteoid osteoma

Nidus location	n	%
Lower extremity	29/38	%76.3
Femur	14	%36.8
Tibia-Fibula	9	%23.7
Foot	3	%7.9
Pelvis	3	%7.9
Upper extremity	9/38	%23.7
Hand	5	%13.1
Radius	2	%5.3
Humerus	2	%5.3

Figure 1. Characteristic direct radiography for osteoid osteoma; radiolucent nidus surrounded by sclerotic bone located in the distal phalanx of the third finger

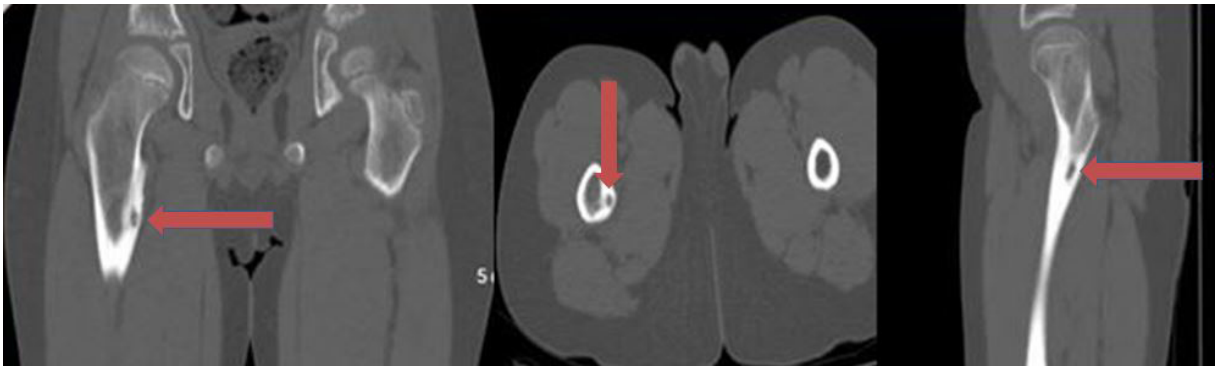

Figure 2. View of the nidus at the level of the right femur trochanter minor detected by computed tomography

that woke them from sleep at night. It was determined that 29 (76.3%) patients responded to oral salicylates and NSAIDs. The mean time from the onset of symptoms to diagnosis was 6.2 months (range 3-40 months).

Plain radiography is the first test required to diagnose OO. Hence, x-rays were obtained for all 38 cases to set the diagnosis of the tumor. The typical appearance on X-ray is of the sclerotic bone surrounding a radiolucent nidus (Figure 1). The method that best visualizes the nidus is computed tomography, so it was determined that 37 patients (97.4%) had CT scans (Figure 2). MRI is less successful in imagining cortical bone, periosteal reaction, and calcifications than CT. It was observed that an MRI was performed on 26 patients (68.4%) (Figure 3). Bone scintigraphy is highly sensitive to the determination of OO localization. The bone scintigraphy images of 19 patients were examined (50 %).

For patients whose pain does not recover with medical treatment, the treatment for OO is surgical excision. Successful treatment is defined as complete surgical excision of the nidus. The currently used surgical methods are curettage, en-bloc (wide) resection, and percutaneous radiofrequency ablation. In the surgical treatment of the 38 patients in this study, the nidus was excised with the en-bloc resection method (Figure 4) or burr-down-assisted intralesional curettage (Figure 5). Burr-down-assisted intralesional curettage was applied to most cases (n: 29). Nidus was excised in 9 cases where preoperative measurement could not determine the nidus localization. With CT, the bone where the nidus is located is completely imaged, and the distance of the lesion to the anatomical landmarks is measured in the coronal, axial, and sagittal planes. The preoperative surgical approach is determined accordingly. Before the skin incision is made, the location of the lesion is determined intraoperatively with direct radiography, and the surgical procedure is performed. Our main surgical technique is burr-down-assisted intralesional curettage. However, en bloc resection was applied to remove the nidus precisely when the localization could not be precisely measured with preoperative CT. While measurement can be easily made with CT in long bones, it may be difficult to precisely determine the location of the nidus in flat and membranous bones. The

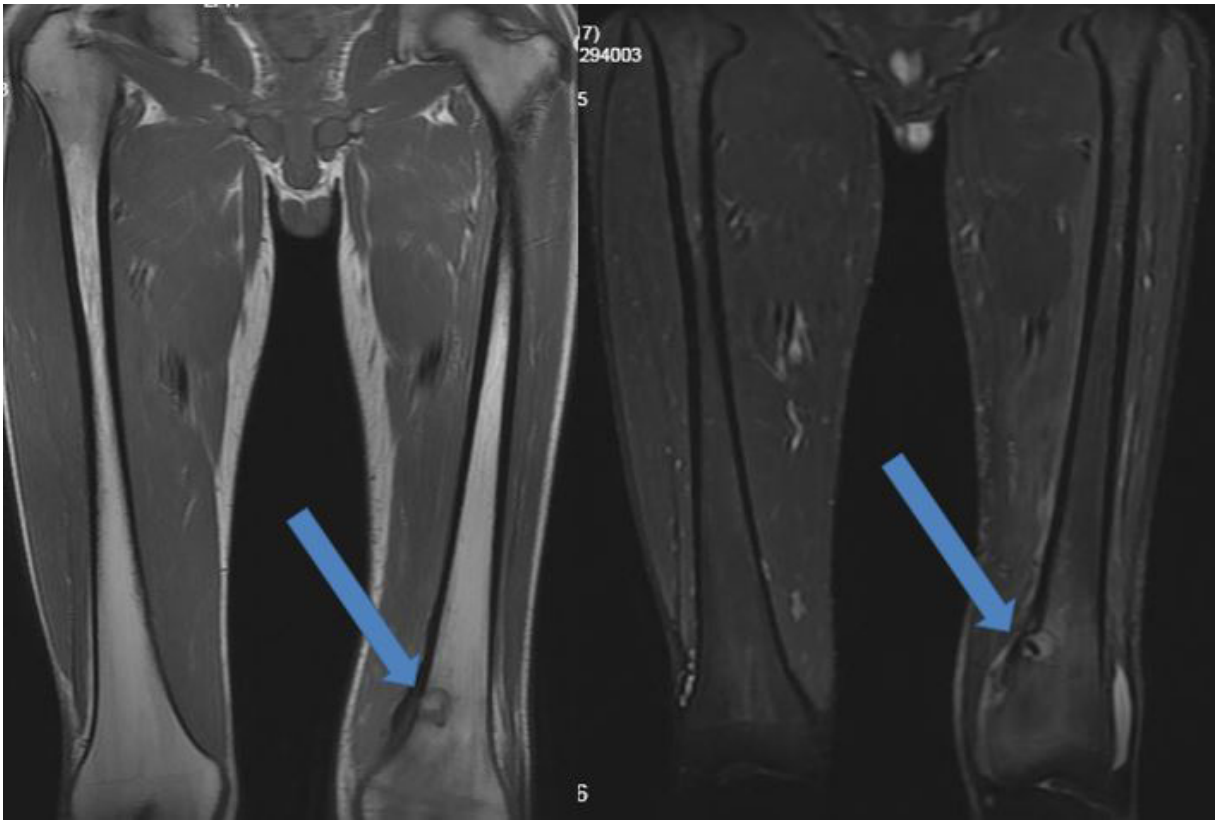

Figure 3. Osteoid osteoma distal to the left femur; typical appearance of the nidus and periosteal reaction on MRI

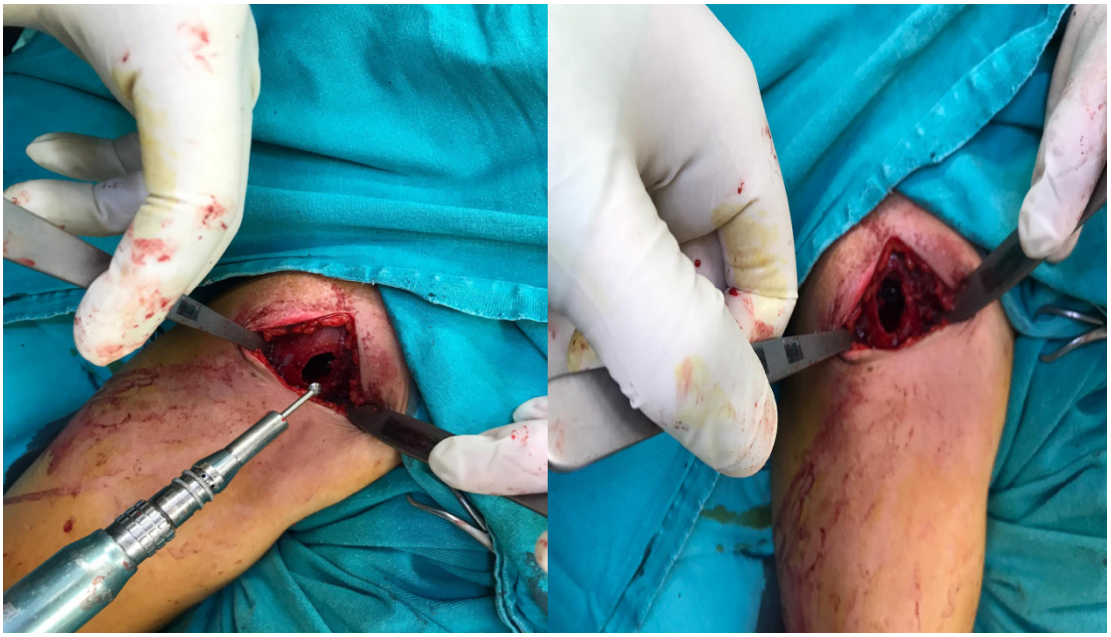

Figure 4. Burr-down-assisted intralesional curettage method in osteoid osteoma surgery

patients were followed up for one day postoperatively and then discharged. In cases where burr down is applied, even if the pathology material does not show the nidus, in patients with a preliminary diagnosis of osteoid osteoma based on preoperative clinical and radiological findings, we can clarify the diagnosis without histopathological correlation after the initial complaints resolve postoperatively. Since the nidus formation is not damaged in cases where we perform en bloc resection, osteoid osteoma can also be diagnosed with pathological evaluation. Histopathological examination of cases undergoing en bloc resection showed thickened trabeculae of bone with adjacent loose fibrovascular stroma around the dense sclerotic bone in most cases. The nidus area was seen with varying thickness and degree of demineralization. In cases where the nidus was curetted, the histopathological evaluation revealed a benign tumoral formation characterized by small young bone trabeculae among bone shavings and sclerotic bone fragments.

In the follow-up examination of the patients on the 14th day postoperatively, x-rays were taken, and the pain was questioned. For one patient with redness and increased heat in the wound site, daily dressings and antibiotic treatment were recommended to treat the superficial wound site infection. At the end of one month of follow-up, the wound site infection of the patient had completely recovered. A significant decrease in pain was observed at the end of 2 weeks in 34 patients, and within the mean two months, the pain had completely recovered in another two patients. In 2 patients, the pain had not recovered at the end of 6 months of follow-up, and as nidus was determined on follow-up CT images, a second surgery was planned. Following the second operation, a significant reduction in pain was seen in the follow-up of all patients.

DISCUSSION

Osteoid osteoma is a benign lesion originating from osteoblasts, constituting 11% of benign bone tumors and 3% of all bone tumours.[4] They are generally seen in the first three decades of life,[5] and males are seen at a rate approximately two-fold higher than females.[3] The patients in the current study comprised 20 (52.6%) males and 18 (47.4%) females, with a mean age of 12.5 years (range 3-36 years), which was consistent with data in the literature. This study investigated osteoid osteoma across all age groups because it can occur in pediatric and adult populations.

The most evident symptom of OO is pain that increases at night and is independent of activity. While pain may initially be intermittent and mild, it is severe and frequent in the advanced period. Generally, there is a response to NSAIDs and oral salicylates.[6] These characteristic findings have been determined in approximately 80% of patients.[7] In lesions determined without pain, there should be suspicion of a diagnosis of OO. In the current study, there was typical pain for OO of severity to wake the patient at night; in 25 (65.7%) cases and 29 (76.3%), there was determined to be a response to oral salicylates and NSAIDs.

Radiological imaging methods are as important as the clinical findings in diagnosing OO. Fusiform thickening in the bone cortex is the most common finding on direct radiographs, and the nidus is generally determined within this thickening. However, the nidus may not be able to be determined on plain radiographs in some cases. In this situation, CT is the most valuable method for visualizing the nidus, determining the localization, and diagnosing.[8] For this reason, almost all patients underwent computed tomography (97.4%).

Additionally, a thin-section CT is recommended for patients with an intra-cortical OO, which may be hard to diagnose due to its localization on the bone. MRI successfully shows soft tissue tumors but lags in diagnosing OO. Diagnosis errors can occur when the nidus is small and edema accompanies the lesion.[9] The study by Davies et al.[10] determined that approximately 35% of lesions could not be visualized with MRI. In the current study, MR images were available for 26 patients (68.4%).

Bone scintigraphy is a method with high sensitivity for OO. It is a helpful test when the lesion cannot be determined on direct radiographs, especially in those with atypical

symptoms.[11] The current study examined bone scintigraphy images of 19 patients (50%). Although imaging methods are crucial, a definitive diagnosis is established with the pathological visualization of the nidus. It must not be forgotten that OO can present with different localizations and an atypical clinical history. It can be confused with osteomyelitis, Brodie abscess, eosinophilic granuloma, osteoblastoma, and other benign bone masses.[12] Therefore, from the initial presentation of the patient's symptoms, each stage of diagnosis and treatment must be performed with care.

NSAIDs and oral salicylates are conservative treatment options for cases with OO. However, the need for long-term drug use and reports that some lesions have transformed into osteoblastoma in this period have pushed the conservative treatment option into the background. Surgical treatment options are wide surgical resection (en-bloc resection), burr-down-assisted intralesional curettage, and percutaneous RFA.[13,14] The success of surgical treatment depends on the complete removal of the nidus. Following removing the nidus, there is a significant reduction in the pain specific to OO. If the severity of the pain is not decreased or continues, this suggests that the nidus has not been completely removed.[15] In 2 patients in the current study, CT was performed on which the nidus was visualized as the pain did not recover during follow-up. The second surgery was planned because of incomplete surgical excision in the first operation.

Wide surgical resection (en-bloc resection) is the extensive removal of the lesion with the surrounding bone. However, this method can cause complications in intra-articular regions, which are difficult to reach. Moreover, internal fixation, bone grafting, or immobile follow-up may be required after the procedure.[16] In cases where the tumor is localized near the neuro-vascular bundle, it is surgically challenging to obtain wide resection. In the burr-down-assisted intralesional curettage method, the nidus is reached by passing through the cortex with a high-speed burr. With curettage of the nidus, it is separated for histopathological examination.[14] In both surgical methods, difficulties can be experienced in locating the nidus. In the current study, the incision region was marked on the skin from an X-ray, and CT was taken preoperatively to determine the localization of the nidus. During the operation, if the nidus could be seen on fluoroscopy, the region was marked with a Kirschner wire, reaching the nidus by passing through the cortex with the burr-down method, and curettage was then performed. In cases where the nidus could not be seen on fluoroscopy, wide surgical resection was preferred, considering the lesion localization. While the nidus is shown in the pathological diagnosis following wide surgical resection, it may not always be able to be seen in the curettage method. The point to be considered here is the patient's clinical condition and the fact that the nidus is not seen radiologically in the postoperative period.

The radiofrequency ablation method is the gold standard in treating OO.[3] RFA was first used by Rosenthal et al., [17] a technique based on the thermal necrosis principle. In a series of 263 cases, Rosenthal et al. reported a success rate of 91%. With this method, the bone integrity is not disrupted, and the patient can be discharged on the day of the procedure. However, the disadvantages of this method are that no sample can be taken for pathological diagnosis, there is radiation exposure, the risk of thermal injury, and high costs.

Limitations

The study has certain limitations. The main limitation of my research is its retrospective nature, which prevented using a scoring system to visualize patients' preoperative and postoperative pain. Additionally, despite operating on more patients, the patient population was reduced due to insufficient data in the archives. Prospective studies comparing radiofrequency ablation and surgical treatment outcomes are needed, using data from a larger number of patients.

CONCLUSION

The critical points in the diagnosis of OO are the character of the pain and the radiological visualization of the nidus. In cases where the pain wakes the patient from sleep at night and responds to NSAIDs and salicylates, OO must be kept in mind. Fine-slice CT and bone scintigraphy are used to visualize the nidus, especially if it is intracortical. The main aim of treatment must be the complete removal of the nidus, and the operation should be planned by determining the lesion localization preoperatively. The radiological disappearance of the nidus and recovery of the pain demonstrate the success of the treatment.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the Ondokuz Mayıs University Clinical Research Ethics Committee (Date: 18.05.2024, Decision No: 2022-258).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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Clinical outcomes and pathologic results following identification of appendicitis

Yaşar Kandur[1], Ayşegül Alpcan[1], Yasemin Dere Günal[2], Hacer Fulya Gülerman[1], Mustafa Kemal Arslan[2], Sema Zergeroğlu[3], Serkan Tursun[1], Şule Toprak[1], Ömer Lütfi Koyuncu[1]

[1]Department of Pediatrics, Faculty of Medicine, Kırıkkale University, Kırıkkale, Turkiye
[2]Department of Pediatric Surgery, Faculty of Medicine, Kırıkkale University, Kırıkkale, Turkiye
[3]Department of Medical Pathology, Faculty of Medicine, Kırıkkale University, Kırıkkale, Turkiye

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Corresponding Author: Ayşegül Alpcan, ozcalk@yahoo.com

ABSTRACT

Aims: Acute appendicitis (AA) is one of the most frequent clinical pathologies for urgent surgery in children We aimed to investigate the occurrence and distribution of pathological findings in appendectomy specimens from patients initially diagnosed with AA.

Methods: The demographic information and histopathological findings of patients who underwent appendectomy at our center between 2011 and 2021 were retrospectively analyzed.

Results: A total of 259 patients were included in the study. The patients were aged 38-212 months (mean 143±39), with 180 (69.5%) male patients. Based on the histopathological results, 63 (24.3%) patienst had lymphoid hyperplasia (LH), 109 (42.1%) AA, 11 (4.2%) suppurative appendicitis (SA), 46 (17.8%) phlegmonous appendicitis (PA), and 30 (11.6%) gangrenous/necrotizing appendicitis (GA). Twenty (31.7%) patients with LH and 16 patients (53.3%) with GA had an invisible appendix on ultrasound. The leukocyte count and appendix diameter were significantly lower in LH than in the other groups (for all comparisons, p<0.001). CRP level was significantly higher in the complicated groups (GA, PA, SA) than the LH and AA groups. The appendix diameter was significantly higher in the GA group than in the PA group (p=0.049). We found a positive correlation between appendix diameter (AD) and preopertaive leukocyte count, and the duration of hospitalization in days (r=0.265, p=<0.001; r=0243, p=0.001). On the other hand, there was no correlation between appendix diameter and CRP. The binary logistic regression analyses showed that high appendix diameter was a risk factor fo CA (OR:0.206, CI: 95%, 1.061-1.422, p= 0.006).

Conclusion: The high rate of complicated cases (33.5%) we found in our study shows that appendicitis can still be complicated. Additionally, the conclusion has been drawn that even in serious cases such as GA, ultrasonography (US) may overlook appendicitis at a high rate. Finally new diagnostic methods should be developed for cases that do not require surgical intervention, such as LH and eosinophilic gastrointestinal pathologies (colitis).

Keywords: Pathology, acute appendicitis, suppurative appendicitis, phlegmonous appendicitis, gangrenous/necrotizing appendicitis.

INTRODUCTION

Acute appendicitis (AA) is one of the most frequent clinical pathologies for urgent surgery in children.[1] The prevailing pathogenesis involves an initial phase characterized by blockage of the appendicular lumen. The resulting obstruction leads to increased mucus secretion, bacterial growth, luminal distension, and elevated intraluminal pressure.[2,3] The subsequent stage occurs when bacteria can penetrate the luminal wall, inducing transmural inflammation or suppurative appendicitis. During this stage, the inflammation extends to the parietal peritoneum and other surrounding structures, known as periappendicitis. Ultimately, intramural venous and arterial thromboses develop in the later stages, resulting in gangrenous appendicitis.[4,5] Ultrasonography (US) is a widely utilized technique for diagnosing acute appendicitis. The specific criteria identifying the appendix is a fluid-filled, non-compressible, blind-ended tubular structure with a diameter of greater than 6 mm.[6,7]

Accordingly, the presence of edema and polymorphonuclear leukocytes along the mucosa, submucosa, or throughout the entire wall of the appendix was considered as AA; the presence of necrosis in the appendix wall and/or the surgeon indicating the observation of purulent material inside the abdomen and/or a perforation in the appendix wall was considered as complicated appendicitis (CA)[8]; reactive follicular hyperplasia was considered as lymphoid hyperplasia (LH). A phlegmonous appendicitis (PA) is characterized as an inflammatory tumor composed of the inflamed appendix, its neighboring viscera, and the greater omentum and a suppurative appendicitis (SA) represents an advanced stage of appendicitis that develops when bacteria and inflammatory fluid, accumulated in the appendix lumen, obstruct the lymphatic and venous drainage.[9,10] So, when the appendix is obstructed, it first leads to acute appendicitis; if the treatment is delayed, it progresses to phlegmonous appendicitis as inflammation increases. Subsequently, if the appendix wall undergoes ischemia, it becomes partially gangrenous in some areas. If still left untreated, perforation occurs from the gangrenous portions.[11]

The histopathological features of a removed appendix, particularly in children, significantly impacts patient management. To address this, we aimed to investigate the occurrence and distribution of pathological findings in appendectomy specimens from patients initially diagnosed with acute appendicitis.

METHODS

The ethics committee approval of the study was obtained from the Kırıkkale University Clinical Research Ethics Committee (Date:28.02.2024, Decision No: 2024.02.30). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

The demographic information and histopathological findings of patients who underwent appendectomy at Kırıkkale University Hospital between 2011 and 2021 were extracted from the hospital's electronic record system and retrospectively analyzed. The patients presented to the pediatric emergency department and the pediatric gastroenterology outpatient clinic with complaints of abdominal pain at the time of admission. Clinical and demographic features were documented, encompassing patient age and gender, clinic, time of appendicitis, type of appendectomy, ultrasonographic and/or tomographic findings, preoperative serum CRP, hemoglobin, leukocyte count, and postoperative histopathological diagnosis.

For the patients included in the study, appendectomy was performed either through an open or laparoscopic technique based on the individual preference of the surgeon. The precise diagnosis of operated patients was confirmed histopathologically.

Statistical Analysis

The normality of the data distribution was assessed using the Kolmogorov-Smirnov test. Differences between the groups in terms of continuous variables in two and three groups were evaluated using the Student's t-test, and when appropriate ANOVA test was employed. Differences in proportions were evaluated using the chi-square test. Correlations between parameters were assessed using Pearson/Spearman correlation tests. Regression analysis was used to assess the relationship between appendix radius and related parameters. A p-value of less than 0.05 was considered statistically significant. Statistical Package for Social Science (SPSS) version 21.0 (SPSS, Chicago, IL, USA) was used for all statistical analyses.

RESULTS

A total of 259 patients were included in the study. The patients were aged 38-212 months (mean 143±39), with 180 (69.5%) male patients. The laparoscopic surgery technique was used in 98 (37.8%) interventions and the classical approach in 161 (62.2%) interventions. The postoperative hospitalization duration in days was statistically shorter in patients who underwent laparoscopy (3.0±1.1 vs 3.6±1.5 days, p<0.001). Ultrasonography was performed in all patients. In 59 (22.8%) patients the appendix was invisible in US. The mean appendix diameter (AD) was 8.3±2.1mm. Out of these patients, CT was performed in 9 patients. In 7 (2.7%) patients the appendix was retrocecal. Twenty-five (9.6%) patients also had perforation.

The seasonal distribution was as follows: 72 (27.8%) patients presented in spring, 56 (21.6%) in summer, 60 (23.2%) in autumn, and 71 (27.4%) in winter. As a significant observation; 36.5% of the LH patient group were diagnosed in winter.

Based on the histopathological results, 63 (24.3%) patienst had LH, 109 (42.1%) AA, 11 (4.2%) SA, 46 (17.8%) phlegmonous appendicitis (PA), and 30 (11.6%) gangrenous/necrotizing appendicitis (GA). So 33.5% of the patients had CA. Twenty (31.7%) patients with LH and 16 patients (53.3%) with GA had an invisible appendix on US report. So, we divided the patient in to 3 groups according to the pathology specimens: LH, AA, CA (Table 1).

Table 1. Comparison of pathologic groups in mean of demographic, clinical and laboratory parameters

Variable	Lymphoid hyperplasia n=63	Acute appendicitis n=109	Complicated appendicitis n=87	P-value	Post Hoc analysis A=between LH and AA B=between LH and CA C=between AA and CA
Gender (female) n (%)	22 (34.9)	27 (24.8)	29 (33.3)	0.293	
Mean age (month)	114±39	143±38	141±42	0.862	
Mean leukocyte count /µl	10548±5109	15728±4687	15858±4763	**<0.001**	**A=<0.001 B=<0.001** C=0.99
Mean hemoglobin (g/dl)	13.1±1.3	13.4±1.2	13.1±1.2	0.266	
Mean CRP (mg/L)	14.9±3.6	34.8±5.6	61.7±8.9	<0.001	A=0.145 **B=0<0.001 C=0.011**
Mean appendix diameter	6.8±1.5	8.5±1.8	8.9±2.4	<0.001	**A=<0.001 B=<0.001** C=0.736
Mean days of postoperative hospitalization	2.9± 0.8	3.4± 1.3	3.8± 1.7	<0.001	**A=0.019 B=0.001 C=0.047**
Patients hospitalized for more than 3 days n (%)	11 (17.5)	32 (29.6)	43 (49.4%)	<0.001	A=0.077 **B=<0.001 C=0.005**
Operation type (Laparoscopic)	29 (46)	40 (37)	28 (32.2)	0.222	

A comparison of histopathological groups with respect to mean LH, AA and CA revealed no significant difference regarding sex, age, and hemoglobin level. The leukocyte count and AD were significantly lower in LH than in the other groups (for all comparisons, p<0.001). CRP level was significantly higher in the CA group than the LH and AA groups. There was a significant difference between the three groups with respect to the mean postoperative hospitalization duration (PHD) (p<0.001). The percentage of patients with CA who were hospitalized for more than 3 days was significantly higher in the CA group than the LH and AA groups (<0.001 and 0.005, respectively). There was no significant difference between the groups regarding the operation type (p=0.222).

A comparison of the complicated pathology groups revealed that there was no significant difference between sex, age, leukocyte count, Hb, and CRP level. The AD was significantly higher in the GA group than in the PA group (p=0.049). The mean hospitalization duration in days was significantly greater in the GA group than the PA and SA groups (for both comparisons, p<0.001). The percentage of patients with GA who were hospitalized for more than 3 days was significantly higher than the PA and SA groups (80% vs 37% and 18.2%, respectively, p<0.001) There was no difference between the groups regarding the operation type (p=0.349) (Table 2).

Table 2. Comparison of complicated appendicits pathologic groups in mean of demographic, clinical and laboratory parameters

Variable	Phlegmonous n=46	Gangrenous/ necrotic n=30	Suppurative n=11	P-value	Post Hoc analysis A=between PL and GN B=between PL and SPP C=between GN and SPP
Gender (female) n (%)	17 (37)	10 (33.3)	2 (18.2)	0.495	
Mean age (month)	148±42	129±42	142±37	0.158	
Mean hemoglobin (g/dl)	15022±4648	16585±5116	17427±3903	0.181	
Mean hemoglobin (g/dl)	13.2±1.3	12.8±1.2	13.5±0.6	0.200	
Mean CRP (mg/L)	50.9±10.9	89.3±19.5	40.0±12.6	0.098	
Mean appendix diameter	8.3±1.9	10.1±3.2	9.6±2.2	**0.040**	**A=0.049** B=0.459 C=0.99
Mean postop hospitalization days	3.1± 1.3	5.2± 1.5	2.8± 1.0	**<0.001**	A<0.001 B=0.362 **C<0.001**
Patients hospitalized for more than 3 days n (%)	17(37)	24(80)	2(18.2)	**<0.001**	**A=<0.001** B=0.235 **C=<0.001**
Operation type (Laparoscopic)	16(34.8)	7(23.3)	5(45.5)	0.349	

We found a positive correlation between AD and preopertaive leukocyte count, and the duration of hospitalization in days (r=0.265, p=<0.001; r=0243, p=0.001). On the other hand, there was no correlation between AD and CRP, age (Table 3). The binary logistic regression analyses showed that high AD was a risk factor fo CA (Odds ratio:0.206, Confidence interval: 95%, 1.061-1.422, p= 0.006); however, high leukocyte and CRP levels were not risk factors for CA.

Table 3. Correlation coefficients between appendix diameter and the variables

Variables*	Appendix radius
Age	r=0.0.15, p=0.840
CRP	r= 0.080, p=0.313
Leukocyte	r= 0.265*,p=<0.001*

*p<0.05

DISCUSSION

In our study, we aimed to correlate the pathology data obtained after surgical diagnosis of appendicitis in children with clinical and laboratory findings.

Acute appendicitis is a prevalent cause for urgent abdominal surgery, and globally, appendectomy stands out as one of the most frequently performed surgical procedures.[12,13] The occurrence of AA closely mirrors that of lymphoid development, reaching its peak between the ages of 10 and 30 years. While there is an equal distribution of acute appendicitis cases between genders before puberty, the incidence in males starts to rise gradually during puberty. By the age of 15 to 25, the male-to-female ratio shifts to 2:1 in favor of men.[14,15] The lifetime prevalence of appendicitis is 9%, peaking between the ages of 10 and 14 years.[16] In our study group, the mean patient age was approximately 12 years (143 months), and there was a male predominance (69.5%), which were consistent with previous studies.[14,15]

The use of laparoscopy in pediatric cases offers not only diagnostic precision but also the benefits of minimally invasive techniques, contributing to overall improved outcomes and patient satisfaction.[17] In recent years, laparoscopic appendectomy has become a standard therapeutic procedure for acute appendicitis in many hospitals. Approximately 1/3 of patients underwent laparoscopic appendectomy in our study group. The postoperative hospital stay was also shorter in our laparoscopic group in our study.[18,19]

In this study, we found a positive correlation between leukocyte count and AD. Besides, a high leukocyte count was not found as a risk factor for CA, but high AD was. In addition, we found no correlation between AD and CRP. Moreover, a high CRP level was not a risk factor for CA. In our opinion these findings weaken the use of CRP in appendicitis. Likewise, Daldal et al.[20] also found that CRP was not useful in predicting AA, unlike leukoyte count.

The diagnosis of AA primarily relies on assessing the patient's symptoms, medical history, and the results of physical examination, and most importantly, the US examination. In a study by Abu-Yousef et al.[21] the sensitivity of US in diagnosing appendicitis was calculated as 80%. According to their findings, US accurately diagnosed two out of three cases reported with a pathological diagnosis of appendicitis. In another study, the sensitivity of US was determined to be 96.4%.[22] The accuracy rate of US was significantly high based on the decision made in accordance with the patient's clinical presentation. However, the appendix was invisible in US in our study group in nearly 1/3 of patients with LH and nearly half of the patients with GA. So, our result showed that an invisible appendix did not exlude the disease, even in its severe form (GA) like previous studies.[23]

In the US examination, the mean AD was 6.8±1.5 in LH group, which was significantly lower than the radius in AA and CA. An appendix diameter over 6 mm has been found to be significant in previous studies.[24,25] Previous studies found a positive AA rate of 88.4% in patients with an AD above 6 mm, which was statistically significant compared to the group with an AD below 6 mm.[20] In a study conducted by Xue, it was found that an appendix diameter of 6-8 mm, in particular, led to false-positive results.[26] This narrowed

the gray zone for distinguishing between appendicitis and lymphoid hyperplasia in the differential diagnosis. The diameter of the appendix appears to be the most crucial criterion in differentiating appendicitis from lymphoid hyperplasia.[6] This underscores the significance of the gray zone within the 6-7 mm diameter range. In patients with AA, the AD was found to be 8.5 mm. In cases of lymphoid hyperplasia, this measurement was even lower. In our opinion, when one suspects appendicitis, the revised radius diameter should be 8 mm. The less the diameter the more likely the pathology of LH.

The pelvic cavity is the most common location for the appendix, followed by a descending order of the intraperitoneal position (31-74%) and retrocecal position (26-65%), which are also prevalent.[27,28] In some cases, patients may exhibit atypical symptoms and physical findings, potentially causing a delay in diagnosis and increased complications. An atypical presentation could be associated with the appendix's position. For instance, an ascending retrocecal appendicitis, characterized by right upper abdominal pain, may be clinically indistinguishable from acute pathologies involving the gallbladder, liver, biliary tree, right kidney, and right urinary tract. Here, in our study, the rate of retrocecal appendicitis was relatively low (%2.7).

It is believed that the perforation of the appendix typically occurs within 24 to 36 hours after the symptom onset. Perforated appendicitis constitutes around 20-30% of cases in children aged 10-17 years with appendicitis, and it is more frequently observed in younger children.[29,30] We found a lower rate, which was 9.6%. The ease of patients reaching a doctor and the prompt availability of ultrasound facilities lead to such a relatively low perforation rate in our center. We found a higher perforation rate and appendix radius in gangrenous appendicitis than the flamenetous one, as expected. In GA, perforation occurs more frequently as a result of a focal abscess, large hemorrhagic ulceration, and gangrenous necrosis.[31]

Lymphoid hyperplasia appears to be a physiological response to inflammation rather than the primary cause of appendicitis. It has been linked to inflammatory conditions.[32] So, this explains the high rate of LH in winter in our study.

Limitations

Our study has several limitations. It is an observational study that outlines outcomes. Additionally, our data are constrained by what was available in the electronic medical records. Regarding pathology reports, as multiple pathologists conducted the reports, there may be some variability in the analysis and reporting of these specimens. Although the pathology results for each case were discussed and classified in consultation with a single pathologist during data collection, individual pathology specimens were not individually reviewed.

CONCLUSION

The high rate of complicated cases (33.5%) we found in our study shows that appendicitis can still be complicated. Additionally, the conclusion has been drawn that even in serious cases such as GA, US may overlook appendicitis at a high rate. As a result of our study, it has been revealed that leukocytosis is a significant determinant in the diagnosis of appendicitis compared to CRP. Furthermore, diagnostic ADs should be reevaluated for the diagnosis of appendicitis. New diagnostic methods should be developed for cases that do not require surgical intervention, such as LH and eosinophilic gastrointestinal pathologies (colitis).

ETHICAL DECLARATIONS

Ethics Committee Approval

The ethics committee approval of the study was obtained from the Kırıkkale University Clinical Researches Ethics Committee (Date: 28.02.2024, Decision No: 2024.02.30).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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MHA MEDIHEALTH ACADEMY

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Original Article

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Safety and benefits of early urethral catheter removal after resectioning the recto urethral fistula during posterior sagittal anorectoplasty

Samiul Hasan[1], Nazmul Islam[1], Refoyez Mahmud[1], Ashrarur Rahman[2]

[1]Department of Pediatric Surgery, Bangladesh Shishu Hospital and Institute, Dhaka, Bangladesh
[2]Department of Pediatric and Neonatal Surgery, Bangladesh Shishu Hospital and Institute, Dhaka, Bangladesh

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Corresponding Author: Samiul Hasan, samiulo45@gmail.com

ABSTRACT

Aims: A urethral catheter must be placed before PSARP (posterior sagittal anorectoplasty) is performed on boys with rectourethral fistula. However, there is no agreement on when the catheter should be removed. Surgeons usually keep the catheter for more than weeks, which is uncomfortable for patients. This study assesses the advantages and safety of removing the catheter early after PSARP.

Methods: We have divided the patients into two groups. In Group 1, patients underwent PSARP with resection of rectourethral fistula (RUF) from January 2017 to February 2021, and the urethral catheter was kept for 14 days. In Group 2, patients were operated on between March 2021 and July 2023, and the urethral catheter was removed on the second day after the operation. The two groups ' demographic and clinical variables were compared using SPSS version 26. Outcome variables were post-operative urinary retention, difficulty in micturition, catheter blockage or dislodgement, fistula recurrence, hospital stay duration, and antibiotic therapy duration.

Results: No patients in either group had urinary retention, recurrence of fistula, or lower urinary complication. However, postoperative hospital stay and antibiotic therapy significantly reduced from 11.2±2.3 days in Group 1 to 4.1±0.5 days in Group 2 ($p<0.01$).

Conclusion: Early catheter removal after PSARP is safe, improves patient comfort, and reduces unnecessary hospital stays and antibiotic therapy.

Keywords: Anorectal malformation, rectourethral fistula, posterior sagittal anorectoplasty, urethral catheterization

INTRODUCTION

Anorectal malformation (ARM) is a complex congenital condition. The type and severity of the anomaly can vary significantly between males and females. In boys, the most common type of ARM is rectourethral fistula, where the rectum ends in the urethra, either in the bulbar or prostatic urethra.[1] This connection between the rectum and the urethra makes reconstruction challenging, as the two tracts share a common wall for some distance. Separating these two tracts is a critical process that must be done carefully to avoid injuring either.[2] The Pena's posterior sagittal procedure became popular among pediatric surgeons worldwide after its introduction in 1982. This procedure offers excellent visualization of muscle structures, the rectum, and the urethra.[2] Over the years, several changes have been made to simplify the process and enhance the results, such as laparoscopic fistula resection, muscle complex sparing PSARP, and endoscopy-assisted fistula identification.[3-9] In their report, Pena emphasized placing a urethral catheter to prevent urogenital injury and fistula recurrence. Pena's groundbreaking article recommended keeping the catheter in for 10 to 14 days after surgery.[2] Most studies, regardless of whether they use a laparoscopic or perineal approach, recommend leaving the catheter in place for almost a week, and sometimes even longer after resecting a rectourethral fistula. This is due to concerns about the possibility of fistula recurrence or urinary retention during the immediate postoperative period.[5,9-11]

However, long-term use of a urethral catheter can lead to various drawbacks such as increased risk of infection, prolonged antibiotic therapy, longer hospital stays, and even urethral stricture in the long term. Catheter blockage and spontaneous dislodgement cause distress for patients, parents, and surgeons. In a report by Lepor et al.[14], it was found that the catheter caused more discomfort than incision pain after radical retropubic prostatectomy.[12-14]

There is a growing trend towards early catheter removal after urethral procedures. In adults, research has shown that removing the catheter early after anastomotic posterior urethroplasty benefits patients.[12-14]

In children, stent-less urethroplasty has shown better outcomes than stented urethroplasty.[15,16] Snodgrass et al.[17] reported successful repair of urethrocutaneous fistula without requiring urinary diversion. This indicates that the stent does not prevent short-term or long-term complications.

We hypothesized that removing the catheter earlier after the resection of the rectourethral fistula would reduce patient discomfort and a shorter hospital stay without compromising the treatmentoutcome. This study aims to present the outcome of early catheter removal after PSARP surgeryin boys with RUF.

METHODS

Before March 2021, we used to keep the urethral catheter in for 12-14 days after rectourethral fistula resection. After that, we changed our practice to remove it on the second postoperative day. We have compared the demographic and clinical data of these two patient groups. We have included all boys who underwent PSARP from January 2017 to July 2023. Boys without rectourethral fistula, patients with rectovesical fistula (required an additional abdominal approach), abnormal sacrum, and whose stomas are yet to be closed were excluded. Patients who underwent redo PSARP (primary operation done elsewhere) were also excluded. The patients were divided into two groups. Group 1: Patients operated on between January 2017 and February 2021.Group 2: patients who were operated between March 2021 to July 2023. Demographic and clinical variables were compared between the two groups. Outcome variables were post-operative urinary retention, difficulty in micturition, catheter blockage or dislodgement, fistula recurrence, hospital stay duration, and antibiotic therapy duration.

Operative Procedures

In group 1, we strictly followed the Pena procedure. After identifying the fistula, we took multiple stay sutures proximal to it, continued the submucosal dissection up to the bladder neck, and then mobilized the full-thickness rectum. The urethral catheters were left in place for 12 to 14 days. If the catheter became blocked, it was removed. Further catheterization was not attempted in case of spontaneous dislodgement of the catheter. The patients were discharged after catheter removal.

In group 2, we performed a complete proximal separation of the rectum before dividing the fistula. This involved separating the rectum proximal to the fistula in the retrovesical space and pulling it upwards. The fistula was then divided without traction sutures. After surgery, the urethral catheter was removed on the second day, and patients were discharged on the third day. We published this technique earlier.[18]

Ethical Clearance

Ethical approval for this study was obtained from the Institutional Ethic Review Board (IRB) of Bangladesh Shishu Hospital and Institute. (No. Admin/BSHI/2024/2513). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Statistical Analysis

Data were analyzed using the Statistical Package for Social Science (SPSS) version 26. Continuous data were presented as mean ±SD, and the differences between the groups were analyzed using an independent sample T-test. The categorical data were presented as percentages and analyzed using the Chi-square and Fisher's Exact Test. The p-value <0.05 was considered significant.

RESULTS

Data were analyzed on 54 patients who met the inclusion and exclusion criteria. Group 1 had 24 patients, while Group 2 had 30 patients. The mean age at operation was 10.6 ± 9.1 months in group 1 and 2.1 ± 9.3 months in group 2, and there was no significant difference between the two groups (p = 0.57).In group 1, 20 patients had a bulbar urethral fistula, while in group 2, the number was 24, and the difference was not statistically significant (p=0.51). After the early removal of the urethral catheter, group 2 had a significantly shorter postoperative hospital stay and duration of antibiotic therapy. In group 1, three patients experienced a catheter block; in group 2, one had spontaneous catheter dislodgement. Table 1 summarizes the results of patients in either group who had urinary retention, recurrence of fistula, or lower urinary complication. The minimum follow-up period was six months (ranging from 6 months to 4 years). The follow-up schedule included appointments two weeks after stoma reversal, followed by monthly check-ups for 6 months, and then yearly check-ups thereafter. It's worth noting that none of the patients in either group experienced urinary complications during the follow-up period.

Table. Outcome variables

Outcome variables	Group 1 (n=24)	Group 2 (n=30)	p
Postoperative hospital stay (day)	11.2±2.3	4.1±0.5	<0.01
Duration of antibiotics (day)	11.2±2.3	4.1±0.5	<0.01
Catheter blockage	3	0	0.08
Catheter dislodgement	1	1	0.69

DISCUSSION

Before performing PSARP surgery in boys, a urethral catheter must be placed to prevent urethral injury. However, there is no agreement on how long to keep the catheter in place after the surgery. Surgeons tend to keep the catheter in the urethra longer to rest the repaired urethra and avoid urinary retention and fistula recurrence. However, there is no evidence that keeping the catheter in the urethra for a longer period prevents fistula recurrence. Moreover, it can be uncomfortable for patients. Pena et al.[19] stressed the significance of fully separating the rectum and urinary tract and sufficiently mobilizing the rectum to avoid recurring fistulas. A rectum that is inadequately mobilized and fixed under tension or a rectum that is injured, repaired, and has its suture line placed over the repaired urethra can lead to fistula recurrence. A urethral catheter helps delineate the surgery but does not prevent fistula recurrence.[19,20]

Arunachalam and colleagues[21] discussed their experience with urinary retention after PSARP. They found that all of their patients had some form of urinary injury as a cause of retention. It has been reported that a significant number of patients who undergo PSARP experience neurogenic bladder, which is thought to be due to extensive abdominal and retrovesical dissection or an abnormal sacrum. Hong and colleagues[20] found that 10% of patients with neurogenic bladder after primary PSARP at a neonatal age should wait until they weigh at least 25 pounds for definitive reconstruction. However, earlier anatomy reconstruction can help to attain the defecation reflex earlier.[22,23] Our series had a higher mean age of reconstruction than most reported studies, which may be due to the socioeconomic background of our patients.[10,18] No patient in our series had a urinary injury and post-operative retention.

Four patients in our group 1 had catheter-related complications, and we had to remove the catheter early. These patients suffered no complications. Based on this observation and the evidence of successful stent-less urethroplasty in children, we started removing the urethral catheter of group 2 patients on the second postoperative day. This changed approach had no impact on the urinary outcome of these patients. However, it significantly reduced the postoperative hospital stay and the duration of antibiotic therapy.

The study excluded patients with rectovesical fistula, as retrovesical dissection may cause temporary urinary retention. A longer urethral catheterization may benefit these patients.

CONCLUSION

Removing a urethral catheter on the second day after PSARP surgery is safe. This improves patient comfort and reduces the duration of hospital stay and antibiotic therapy without causing urinary complications. During the surgery, complete separation of the rectum from the urinary tract and minimal retrovesical dissection should be prioritized. However, any urological injury during surgery may require a longer catheterization period.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Ethical Committe of Faculty of Institutional Ethic Review Board (IRB) of Bangladesh Shishu Hospital and Institute (No. Admin/BSHI/2024/2513).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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Descriptive analysis of road traffic accidents in children aged 0-2 years*

Yalçın Gölcük[1], Ömer Faruk Karakoyun[2], Halil Emre Koyuncuoğlu[2]

[1]Department of Emergency Medicine, Faculty of Medicine, Muğla Sıtkı Koçman University, Muğla, Turkiye
[2]Department of Emergency Medicine, Muğla Training and Research Hospital, Muğla, Turkiye

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Corresponding Author: Yalçın Gölcük, dryalcingolcuk@gmail.com

ABSTRACT

Aims: This study aims to investigate road traffic accidents (RTAs) involving infants and toddlers, defined as children from birth to 2 years old, focusing specifically on their epidemiology and outcomes.

Methods: A retrospective, single-center, observational, and cross-sectional study was conducted in the Emergency Department of a university-affiliated training and research hospital. Data were collected from July 1, 2019, to January 1, 2024.

Results: During the study period, 659 cases involved pediatric RTAs patients (individuals under 17 years old), with 41 cases specifically concerning infants and toddlers. These patients had a mean age of 12.98 ± 5.64 months, and 27 (65.9%) were boys. The median Pediatric Trauma Score for was 9 (range: 5-12) while the median pGCS score was 15 (range: 14-15). Motor vehicle accidents were the leading cause of injuries, accounting for 92.6% of cases, followed by motorcycle accidents (4.8%) and pedestrian-vehicle collisions (2.6%). Hospitalized patients exhibited various injuries, including femur fractures, subdural hematoma, orbital roof fracture, scalp hematomas, and lung contusion. Surgical intervention was required in only one case for a femur shaft fracture. Fortunately, no in-hospital deaths occurred among the study participants.

Conclusion: This study underscores the importance of adult supervision to prevent RTAs and emphasizes the critical need for strict enforcement of child passenger safety laws to reduce the incidence of motor vehicle accidents involving infants and toddlers.

Keywords: Toddler, traffic accident, infant, emergency department, trauma

* An earlier version of this study was presented as a preliminary report at the 11th Intercontinental Emergency Medicine Congress, Side/Antalya, 16-19 May 2024.

INTRODUCTION

Road traffic accidents (RTAs) pose a formidable global public health challenge, placing a profound burden on societies and healthcare systems, particularly concerning pediatric populations. According to the World Health Organization (WHO), RTAs are a leading cause of injury-related mortality in children, causing not only immediate physical trauma but also long-term disabilities, psychological distress, and significant economic strain.[1] Despite extensive efforts to mitigate the general impact of RTAs, there remains a critical need to investigate the specific vulnerabilities associated with early childhood.[2]

Neonates, infants, and toddlers constitute an exceptionally vulnerable demographic within the spectrum of RTAs. Their developmental immaturity, limited mobility, and complete reliance on caregivers for safety render them particularly susceptible to severe injuries, even in relatively minor collisions. Their small physical size and physiological fragility exacerbate these risks, while their limited capacity for communication can hinder effective diagnosis and treatment. Additionally, their dependence on properly fitted safety restraints and the absence of motor and cognitive skills to anticipate or avoid hazards significantly heighten their risk of severe outcomes in traffic accidents.[3]

In 2021, the United States reported 42,939 traffic fatalities, of which 1,184 (3%) were children. Analysis of trends over nearly a decade reveals significant disparities among pediatric age groups, with fatalities among the youngest children increasing markedly, while older age groups experienced declines. This trend underscores the particular vulnerability of very young children in RTAs.[4] However, there is a notable lack of similar data in Turkey, highlighting the need for targeted research to address this gap and inform effective preventive strategies.

This study aims to fill this gap by providing a comprehensive analysis of the characteristics, patterns, and outcomes of RTAs specifically affecting neonates, infants, and toddlers. To our knowledge, this is the first study in Turkiye to focus on RTAs within this age group. By concentrating on this highly vulnerable population, the research seeks to offer nuanced insights that extend beyond the general pediatric context, thereby facilitating the development of targeted preventive strategies.

METHODS

Study Design and Setting

This retrospective, single-center, observational, and cross-sectional analysis was performed in the Emergency Department (ED) of a university-affiliated training and research hospital located in Muğla, Turkiye. The study involved a systematic collection of data from consecutive neonates, infants, and toddlers patients admitted to the ED during the period from July 1, 2019, to July 1, 2023. The institution, boasting over 600 beds, handles an estimated 140,000 ED visits annually. Ethical approval was secured from the Institutional Ethics Review Board of Muğla Sıtkı Koçman University (Date: 17.07.2024, decision number: 88). Given the retrospective design, the requirement for obtaining written informed consent from patients was waived. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Selection of Participants:

The pediatric age cutoffs in this study were categorized according to the Munich Age Classification System (MACS), a widely recognized and universal age classification system used in pediatric emergency medicine: Neonate (up to the 27th day of life), infant (30 days – 12 months), and toddler (13 months – 2 years).[5] Our study included only children aged 0-2 years who were involved in an RTA, while those older than 2 years were excluded. Additionally, patients who were lost to follow-up or had missing data were also excluded from the study.

Data Collection

Data collection was rigorously executed using a standardized spreadsheet to ensure comprehensive and precise documentation of relevant parameters. Upon admission to the ED, age, sex, and types of RTAs were meticulously documented. Additionally, a comprehensive range of ancillary data was systematically collected, encompassing diagnostic methods, imaging findings, laboratory test results, final in-patient diagnoses, and key outcome variables, including the need for hospital admission, surgical interventions, length of hospital stay (LOS), and all-cause mortality. Notably, the initial Pediatric Glasgow Coma Scale (pGCS) score and Pediatric Trauma Score (PTS) were calculated for each patient, offering crucial assessments of trauma severity and aiding in the evaluation of clinical outcomes.

Statistical Analysis

The normality of the data distribution was assessed using the Kolmogorov-Smirnov test. Continuous variables were presented as either mean±SD or median (range) depending on their normality. Categorical variables were expressed as absolute values and percentages. Demographic, laboratory, and clinical variables were compared between the two groups, with differences in admission and discharge status assessed using the Mann-Whitney U test for continuous variables and Chi-squared test for categorical variables. For all tests, p>.05 was considered statistically significant. All analyses were performed using SPSS version 25.0 statistical software (SPSS Inc., Chicago, Ilinois).

RESULTS

Our study includes 41 children under the age of 2 who were brought to the emergency department due to RTAs. Of these cases, 8 occurred in the first year, 6 in the second year, 10 in the third year, and 17 in the final year of the study period. The patient flow diagram of the study design is illustrated in Figure.

The distribution across age groups was as follows: 0 neonates (0%), 18 infants (43.9%), and 23 toddlers (56.1%). Our study focused on a cohort of 41 infants and toddlers, with a mean age of 12.9 ± 5.6 months (range: 3 to 24 months), of whom 27 (65.9%) were male. The median PTS for this cohort was 9 (range: 5-12), while the median pGCS score was 15 (range: 14-15). Table details the baseline characteristics of the enrolled patients, categorized by their admission or discharge status.

Injury mechanisms varied, with motor vehicle collisions (MVCs) (n=38, 92.6%) being the predominant cause, followed by motorcycle accidents (n=2, 4.8%) and pedestrian-vehicle collisions (n=1, 2.6%). RTAs were most frequent in the summer (n=21, 51.2%), with the highest occurrence in July (n=9, 22%) and on weekdays (n=23, 56.1%).

Table. Baseline characteristics of enrolled patients by admission or discharge status

Variables	Total (n=41)	Discharged (n=32)	Admitted (n=9)	P value*
Demographic data				
Age (months)	12.9 ± 5.6	13.5 ± 5.8	11.0 ± 4.6	0.195
Sex (man/woman)	27/14	21/11	6/3	0.954
Day type (weekdays/weekends)	23/18	19/13	4/5	0.425
Hematology profile				
White blood cell count (x10^3/µL)	13.3±5.1	13.6±5.2	12.1±4.8	0.429
Red blood cell count (x10^6/µL)	4.3±0.5	4.2±0.5	4.7±0.5	0.060
Hemoglobin (g/dL)	11.6±1.6	11.5±1.7	12.0±1.1	0.154
Hematocrit (%)	35.1±5.4	34.7±5.5	36.3±3.6	0.164
Platelet count (x10^3/µL)	319.6±110.7	341.0±143.1	243.5±194.0	0.269
Serum chemistry				
Glucose (mg/dL)	112.7±42.9	115.7±47.0	102.2±21.4	0.343
Blood urea nitrogen (mg/dL)	19.4±1.3	19.0±8.2	20.7±9.6	0.793
Creatinine (mg/dl)	0.34±0.09	0.35±0.09	0.32±0.11	0.312
Sodium (mmol/L)	136.5±2.7	136.8±2.7	135.4±2.4	0.242
Potassium (mmol/L)	4.6 ±0.5	4.6±0.5	4.6±0.3	0.865
Calcium (mg/dl)	10.3±0.7	10.3±0.7	10.5±0.8	0.297
Albumin (g/dl)	45.0±3.5	44.8±3.5	45.7±3.3	0.609
Aspartate transaminase (IU/L)	56.5±41.5	60.5±45.4	42.2±18.1	0.128
Alanine transaminase (IU/L)	25.9±25.2	27.1±27.9	21.7±11.3	0.841
Clinical scoring tools				
Pediatric trauma score	9 (5-12)	9 (9-12)	8 (5-9)	<0.001
Pediatric Glasgow coma scale score	15 (13-15)	15 (15-15)	15 (13-15)	0.327

Data are expressed as mean ± SD, median (range), or count for categorical variables unless otherwise indicated. *: The *P* value reflects the comparison between discharge and admission patient variables.

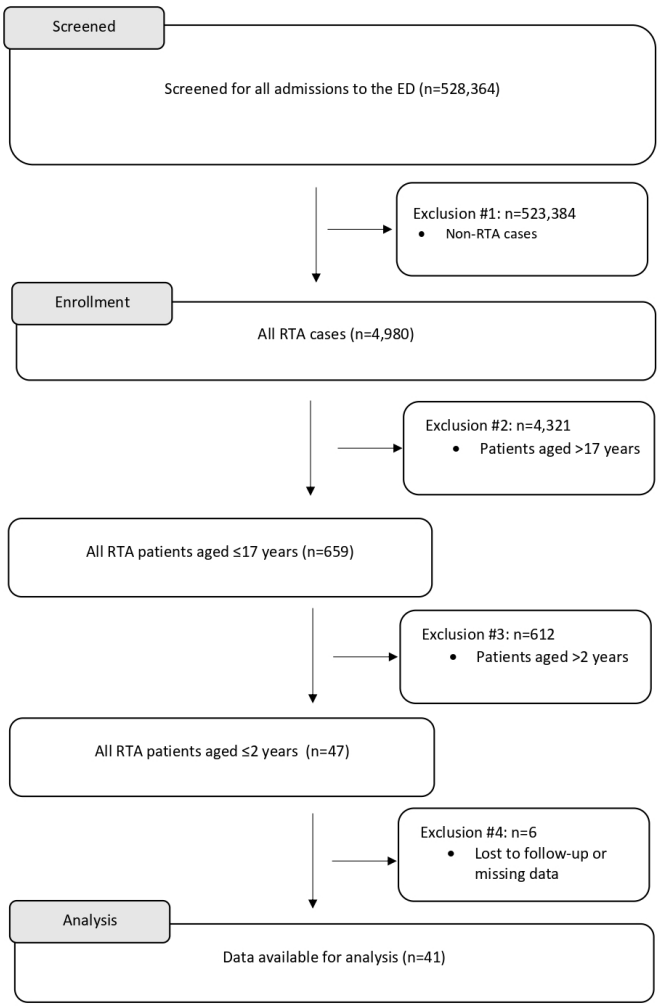

Figure. Flow diagram of the study design

Diagnostic management revealed that nearly all patients (n=38, 92.6%) underwent extended focused assessment with sonography in trauma. Computed tomography (CT) scans, primarily for suspected head injuries, were conducted in 21 cases (51.2%), while plain X-rays were performed in 10 cases (24.3%). Among these patients, injuries included 2 femur fractures, 1 subdural hematoma, 1 orbital roof fracture, 2 extensive scalp hematomas, 1 lung contusion, and 2 cases of vital abnormalities, leading to the hospitalization of 9 patients (21%). Additionally, only 1 patient was admitted to the pediatric ICU, and surgical intervention was necessary for 1 patient with a femur shaft fracture. The mean LOS for the cohort was 4.7 ± 2.9 days, and no in-hospital deaths were reported.

DISCUSSION

This study offers critical insights into the underexamined subset of RTAs affecting children from birth to 2 years of age, highlighting the urgent need to address the unique epidemiological and outcome-related aspects of these incidents in this particularly vulnerable group. Our findings reveal that motor vehicle accidents are the predominant cause of injuries within this age cohort, underscoring the necessity for targeted preventive strategies. Moreover, the high frequency of head injuries identified through CT scans points to a pressing need for the development of age-specific imaging guidelines to minimize the risks associated with radiation exposure in such young patients.

In 2021, the United States reported 42,939 traffic fatalities, of which 1,184 (3%) were children. A detailed analysis from 2012 to 2021 reveals significant disparities in trends among different pediatric age groups. Fatalities in the under-1 age group increased by 52%, from 60 to 91, while the 1-to-3 age group saw a 31% decrease from 269 to 186. Specifically, from 2020 to 2021, there was a 54% increase in fatalities among children under 1 year, rising from 59 to 91, while the number of fatalities in the 1-to-3 age group remained constant at 186. These statistics underscore the vulnerability of very young children in road traffic accidents.[4]

The injury mechanisms observed in this study reveal that MVCs were the predominant cause of trauma among infants and toddlers, accounting for 92.6% of cases. This underscores the urgent need for targeted preventive measures to address this critical issue. The high incidence of MVCs in our study highlights a significant area for intervention, particularly given the developmental vulnerabilities of this age group. Existing literature underscores the crucial role of targeted safety interventions in mitigating the severity of MVCs involving young children. The use of child safety seats has been shown to significantly lower the risk of fatal injuries, achieving a 71% reduction in infants under 1 year of age and a 54% reduction in toddlers aged 1 to 4 years in passenger cars. In light trucks, these reductions are 58% for infants and 59% for toddlers, respectively.[6] Moreover, research by Rice et al.[7] provides compelling evidence that the proper utilization of car seats substantially decreases the risk of severe injury and mortality among children aged 3 years or younger involved in RTAs. Their findings underscore the superior effectiveness of child safety seats in preventing fatalities during severe collisions, surpassing the protective capability of traditional seat belts. However, it is important to note that our study did not collect data regarding the pre-hospital use of child safety seats or other child safety measures. This absence represents a limitation, as it precludes a comprehensive analysis of the potential protective effects of such interventions in our patient population. Future studies should aim to include these variables to provide a more complete understanding of the factors influencing injury outcomes in this vulnerable demographic.

Effective injury prevention in young children requires a multifaceted approach that extends beyond the deployment of safety devices to include comprehensive educational and awareness initiatives. Britton et al.[8] emphasize the critical importance of educational programs aimed at parents and caregivers to enhance the safety outcomes of child restraint systems (CRS). Despite high levels of self-reported confidence in CRS use among parents, especially those with experience installing only a single system, this confidence often does not align with actual proper installation and usage. This discrepancy reveals a need for further investigation into the factors contributing to the gap between perceived competence and the actual effectiveness of CRS. Moreover, public awareness campaigns focusing on child passenger safety have demonstrated efficacy in promoting safer practices. Bakhurji et al.[9] illustrated that educational interventions delivered via social media substantially increased parental knowledge and awareness regarding the correct use of car seats. Their study highlights the significant impact of social media in disseminating essential safety information and improving

adherence to child restraint protocols, underscoring the potential of these campaigns to advance child passenger safety and reduce risks associated with RTAs involving young children. Policymakers must consider enacting and enforcing stricter regulations on car seat usage, implementing educational programs for parents and caregivers about the importance of proper restraint systems, and enhancing public awareness campaigns focused on child passenger safety.

The use of CT scans in diagnosing injuries in pediatric patients, particularly following RTAs, raises critical concerns about ionizing radiation exposure. Infants and toddlers are especially vulnerable due to their developing tissues and longer life expectancy, which heightens the risk of radiation-induced malignancies. In our study, half of the patients underwent CT scans, a statistic that underscores the importance of meticulously evaluating imaging practices in pediatric trauma care. This widespread use of CT imaging in young patients has sparked an ongoing debate in the medical community, with many experts advocating for the development of age-specific guidelines to ensure CT scans are used judiciously and only when absolutely necessary. Aligning with the ALARA (As Low As Reasonably Achievable) principle, there is an increasing emphasis on minimizing radiation exposure by optimizing CT protocols and considering alternative diagnostic modalities when possible. These efforts are vital to safeguarding the long-term health of pediatric patients while still providing the critical diagnostic information needed to guide effective treatment.[10]

The outcomes observed in our study cohort provide valuable insights into the clinical course and management of RTAs among infants and toddlers. While the majority of patients did not require hospitalization, a notable proportion exhibited significant injuries necessitating further medical intervention. The absence of in-hospital deaths among our study population is reassuring; however, it is imperative to recognize the potential long-term consequences of RTAs in this vulnerable age group, including physical, cognitive, and emotional sequelae. Future research endeavors should focus on longitudinal follow-up studies to elucidate the full spectrum of outcomes and inform comprehensive rehabilitation strategies tailored to the unique needs of infant and toddler survivors of RTAs.

Despite the valuable insights provided by our study, several limitations warrant consideration. Firstly, the retrospective nature of the study design may have introduced selection bias and hindered the comprehensive capture of all relevant data. Secondly, the reliance on a single-center setting limits the generalizability of our findings to broader populations with varying demographic and geographic characteristics. Thirdly, the inclusion of COVID-19 lockdown periods in the study may have led to a relatively small sample size of infants and toddlers involved in RTAs, potentially restricting the statistical power and precision of our analyses. Additionally, the exclusion of patients with missing data or those transferred to other facilities may have influenced the representativeness of our study cohort. Moreover, our study did not collect data regarding the pre-hospital use of child safety seats or other child safety measures, which limits our ability to analyze the potential protective effects of such interventions. Lastly, the absence of long-term follow-up data precludes a comprehensive assessment of the sustained impact and outcomes of RTAs among infants and toddlers beyond the acute care setting. Furthermore, our study is limited by the absence of pre-hospital mortality data, which may affect the comprehensive understanding of the overall outcomes of RTAs involving infants and toddlers.

CONCLUSION

As a result, our study provides valuable insights into the epidemiology and clinical outcomes of RTAs in infants and toddlers, a uniquely vulnerable population. By identifying distinct injury patterns and seasonal trends, we emphasize the need for targeted preventive strategies. The predominance of motor vehicle accidents underscores the critical importance of optimizing child restraint systems and educating caregivers on their correct use. Our findings also reveal the necessity for age-specific diagnostic and management protocols. Future research should focus on evaluating the long-term outcomes of RTAs in this age group and the effectiveness of current preventive interventions.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was initiated with the approval of the Muğla Sıtkı Koçman University Medical Sciences Ethics Committee (Date: 17.07.2024, Decision No: 88).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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Anesthesia practices during magnetic resonance imaging in pediatric patients

Ela Erten. Büşra Eroğlu

Department of Anesthesiology and Reanimation. Gülhane Training and Research Hospital. Ankara. Turkiye

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Corresponding Author: Ela Erten. drelacaliskan@hotmail.com

ABSTRACT

Aims: The use of magnetic resonance imaging (MRI) is becoming increasingly common for diagnostic and therapeutic purposes in pediatric cases. Among children who are too young to cooperate with the procedure or in those with anxiety. anesthesia may be required to minimize excessive motion and optimize image quality. The aim of this study was to determine the efficacy and associated complications of different anesthesia techniques used during MRI in pediatric patients at our hospital.

Methods: Anesthesia charts and computer records of pediatric patients who had undergone MRI under anesthesia between January 2021 and January 2023 in a training and research hospital were retrospectively reviewed. The patients were categorized into four groups according to their anesthesia maintenance protocols to compare their efficacy and associated complications.

Results: Of the 358 included patients. only 2% underwent MRI under general anesthesia using a laryngeal mask airway (LMA). whereas the rest underwent MRI under sedation. In our hospital. the most commonly used technique for MRI under anesthesia in pediatric patients involved sevoflurane inhalation using a simple facemask and airway (54.5%). and the lowest complication rate (0.8%) was observed in those who underwent only anesthesia induction without the administration of an agent for the maintenance of anesthesia.

Conclusion: Outpatient anesthesia is generally considered the most effective and comfortable method for sedation during MRI. The results of this study suggest that anesthesia involving sevoflurane inhalation with a simple face mask applied to preserve spontaneous breathing is an effective and safe method for pediatric patients undergoing MRI.

Keywords: Magnetic resonance imaging. pediatrics. anesthesia. sevoflurane

INTRODUCTION

Outpatient anesthesia is becoming increasingly common in pediatric procedures. and members of the anesthesia team are expected to provide care in very different areas. including. but not limited to. interventional radiology. radiation oncology. and cardiac catheterization laboratories. To provide safe anesthesia. experienced anesthesiologists must be aware of the specific characteristics and environmental risks in these different units and manage perioperative processes accordingly.[1] In pediatric anesthesia management performed outside the operating room. maintenance methods may include intubation. controlled or spontaneous breathing with a laryngeal mask. local anesthesia. and spontaneous breathing with oxygen support. depending on the reason for anesthesia.[2] Magnetic resonance imaging (MRI) performed outside of the operating room is a valuable radiological imaging method for diagnosis and treatment monitoring that is being increasingly used in pediatric patients. who sometimes require anesthesia during the procedure.[3] The need for prolonged immobility in a closed and noisy area. the requirement for intravenous (IV) injections of contrast material. and the anxiety resulting from separation from parents make MRI a highly anxiety-inducing procedure for children.[4] Therefore. anesthesia is the most appropriate method for ensuring this process occurs smoothly.

In pediatric populations. anesthesia for MRI should maintain the hemodynamic balance without harming the physiology and metabolism of patients while ensuring recovery occurs safely in a short time period. as it is usually an outpatient or ambulatory procedure.[5] IV anesthetic agents such as propofol. ketamine. midazolam. and dexmedetomidine as well as inhalational agents such as sevoflurane are used either individually or in combination for sedation in pediatric anesthesia management during MRI.[6] The most critical requirement for anesthesia during such procedures is the provision of equipment that is MRI-compatible.

The aim of this study was to evaluate the anesthesia techniques used during MRI in pediatric patients at our hospital. The secondary aim was to compare the efficacy and associated complications of these anesthesia techniques.

METHODS

This single-center. retrospective cohort study included pediatric patients who had undergone MRI under anesthesia between January 2021 and January 2023 at Gülhane Training and Research Hospital. University of Health Sciences. Ankara. This study was approved by the University of Health Sciences. Gülhane Clinical Researches Ethics Committee (Date: 10.09.2024. Decision No: 2024/441) and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. As the study was retrospective in nature. voluntary informed consent was not obtained from the patients.

This study included all patients with an American Society of Anesthesiologists (ASA) physical status classification of 1–3 who were younger than 18 years of age. who had undergone MRI under anesthesia. and whose medical data were not missing. Data from 358 pediatric patients who met the inclusion criteria were collected retrospectively by reviewing computer records and anesthesia follow-up forms. The patients were categorized into the following four groups according to the anesthesia maintenance practices: Group 1. cases in which no anesthetic agent was administered for anesthesia maintenance; Group 2. cases in which only an inhalational agent was administered for anesthesia maintenance; Group 3. cases in which an IV anesthetic agent was administered for anesthesia maintenance; and Group 4. cases in which both IV and inhalational agents were administered in combination for anesthesia maintenance.

Outpatient or ambulatory anesthesia for MRI was performed by various anesthesiologists. each of whom had more than ten years of experience. The type of anesthesia administered to the patients was determined at the discretion of each anesthesiologist according to the age of the patient. the presence of comorbidities. the anatomical area in which MRI was being performed and the number of areas evaluated. and the duration of the procedure. An MRI-compatible anesthesia device (Lamtec 880; Pneupac. Luton. UK) and bedside monitoring equipment (Invivo 3150 Magnitude MRI Monitor Full System) were used in all cases. with the anesthesia-related equipment being used in the MRI unit. Heart rate. peripheral blood oxygen saturation (SpO2). and capnography (with a face mask. endotracheal tube. or laryngeal mask) were routinely monitored during anesthesia. Sedated patients with a sedation score of 2 or 3 according to the University of Michigan Sedation Scale (UMSS) received follow-up assessments (**Table 1**). When the heart rates of the children fell below the normal limits for their age group.

Table 1. The University of Michigan Sedation Scale (UMSS)

Score	Description
0	Awake and alert
1	Minimally sedated : tired/sleepy. appropriate response to verbal conversation and or sound (calling child's name)
2	Moderately sedated : somnolent/sleeping. easily aroused with light tactile stimulation (lightly touching arm. face and leg)
3	Deeply sedated : deep sleep arousable only with significant physical stimulation (tickling their feet)
4	Unarousable : unresponsive to feet tickle

Table 2. Normal pediatric heart rates

Age (Years)	Range of normal heart rates (beats per minute)
Neonate <30 days	120-160
1-6 months	110-140
6-12 months	100-140
1-2 years	90-130
3-5 years	80-120
6-8 years	75-115
9-12 years	70-110
13-16 years	60-110
>16 years	60-100

bradycardia was assumed. and atropine (0.02 mg/kg. IV) was administered (Table 2). When SpO_2 levels fell below 90%. hypoxia was assumed. and necessary interventions were performed. Following the procedure. patients were transferred to the recovery room. where the SpO_2 and heart rate were continuously monitored and evaluated according to the Modified Aldrete Score (Table 3); the patients were discharged once the score reached 10.

Demographic data. ASA information. details about the MRI acquisition sites and number of sites. contrast agent use. peripheral vascular access management. premedication. anesthesia induction and maintenance. airway management. MRI acquisition. total length of stay. movement during the procedure. complications encountered. and interventions were recorded in the data forms and analyzed.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows. version 25.0 (IBM Corp.. Armonk. NY. USA). The normality of the data distribution for each variable was determined using the Kolmogorov-Smirnov test. Data are expressed as numbers. percentages. median values with an interquartile range (IQR). or minimum and maximum values. Categorical variables were evaluated using the chi-square test. quantitative measurement data were evaluated using the Kruskal–Wallis test. and intragroup pairwise comparisons were conducted using the Mann-Whitney U test. Statistical significance was set at $p<0.05$. For intragroup pairwise comparisons of continuous data (six paired groups). the Bonferroni correction was applied. and a corrected p value of 0.0083 (0.05/6) indicated a statistically significant difference.

Table 3. Modified aldrete scoring system

Criteria	Characteristics	Points
Activity	Able to move 4 extremities	2
	Able to move 2 extremities	1
	Unable to move extremities	0
Respiration	Able to breathe deeply and cough freely	2
	Dyspnea or limited breathing	1
	Apneic	0
Circulation	BP +/- 20% of pre-anesthetic level	2
	BP +/- 20-49% of pre-anesthetic level	1
	BP +/- 50% of pre-anesthetic level	0
Consiousness	Fully awake	2
	Arousable on calling	1
	Not responding	0
Oxygen saturation	Able to maintain O_2 saturation >92% on room air	2
	Needs oxygen to maintain O_2 saturation >90%	1
	O_2 saturation <%90 even with supplemental oxygen	0

(BP:Blood Pressure. O_2 : Oxygen)

Table 4. Demographic data. ASA scores. comorbidities and antiepileptic drug use of the groups

	Total n=358	Group 1 n=58 (%16.2) No maintenance anesthesia	Group 2 n=219 (%61.1) Maintenance with inhalation anesthesia	Group 3 n=63 (%17.5) Maintenance with IV anesthesia	Group 4 n=18 (%5) Maintenance with inhalation and IV anesthesia	P
ASA. n (%)						
I	185 (51.7)	37 (63.8)	115 (52.5)	27 (42.9)	6 (33.3)	
II	154 (43.0)	16 (27.6)	94 (42.9)	33 (52.4)	11 (61.1)	
III	19 (5.3)	5 (8.6)	10 (4.6)	3 (4.8)	1 (5.6)	0.085
Additional Disease. n (%)						
Yes	159 (44.4)	21 (36.2)	93 (42.5)	33 (52.4)	12 (66.7)	
No	199 (55.6)	37 (63.8)	126 (57.5)	30 (47.6)	6 (33.3)	0.067
Gender n (%)						
Woman	137 (38.3)	25 (43.1)	80 (36.5)	25 (39.7)	7 (38.9)	
Man	221 (61.7)	33 (56.9)	139 (63.5)	38 (60.3)	11 (61.1)	0.823
Use of antiepileptic drugs. n (%)						
Yes	44 (12.4)	6 (10.3)	27 (12.4)	9 (14.3)	2 (11.8)	
No	312 (87.6)	52 (89.7)	191 (87.6)	54 (85.7)	15 (88.2)	0.932
Age (Year)	3.0 (0.5-5.0 [0.0-16.0])	3.0 (0.5-4.6 [0.0-16.0])	2.0 (0.5-5.0 [0.0-16.0])	4.0 (2.0-6.0 [0.0-12.00])	3.0 (1.7-6.5 [0.5-10.0])	<0.001
Weight (kg)	13.0 (9.0-20.0 [2.9-63.0])	12.7 (7.8-18.2 [3.0-63.0])	12.0 (8.0-18.0 [2.9-46.0])	16.0 (12.0-22.0 [6.5-41.00])	14.5 (10.0-21.2 [8.0-35.0])	0.001

(IV: Intravenous. ASA: American Society of Anesthesiologists Classification)

RESULTS

Of the 358 children who had undergone MRI under anesthesia. 137 (38.3%) were girls and 221 (61.7%) were boys. In terms of the categorization based on the type of anesthesia administered for maintenance. 219 (61.1%) patients comprised Group 2. 63 (17.5%) made up Group 3. 58 (16.2%) met the criteria for Group 1. and 18 (5.0%) were classified in Group 4. A total of 185 (51.7%) patients had an ASA 1 physical status classification. and there was no statistically significant intergroup difference. A significant intergroup difference was observed in terms of age. with the patients in Group 2 being significantly younger (p<0.001). Similarly. the weights of the children differed significantly between the groups. with those in Group 3 being heavier. (Table 4).

In 316 patients (88.3%). MRI was conducted in one anatomical region. the most common being the brain in 294 cases (82.1%). whereas MRI of more than one anatomical region was performed in 42 cases (11.7%). The highest number of single-region MRI scans was performed in Group 2. which also exhibited the highest use of contrast material (p=0.016 and p=0.001. respectively).

Peripheral vascular access was performed while patients were awake in most cases (76.8%) and was conducted most frequently in Group 1; the most common access site was dorsum of the hand (67.6%). and successful access was most often achieved in a single attempt (80.7%). There was no significant intergroup difference in terms of the number of peripheral vascular access attempts or the access site (Table 5).

Table 5. Peripheral vascular access (PVA) management of the groups

	Total n=358	Group 1 n=58 No maintenance anesthesia	Group 2 n=219 Maintenance with inhalation anesthesia	Group 3 n=63 Maintenance with IV anesthesia	Group 4 n=18 Maintenance with inhalation and IV anesthesia	P
Way of opening PVA . n (%)						
Awake	275 (76.8)	52 (89.7)	157 (71.7)	55 (87.3)	11 (61.1)	
Sedatized state	15 (4.2)	5 (8.6)	5 (2.3)	4 (6.3)	1 (5.6)	<0.001
Under anestesia	68 (19.8)	1 (1.7)	57 (26.0)	4 (6.3)	6 (33.3)	
Opening region of PVA. n (%)						
Over the hand	242 (67.6)	44 (75.9)	137 (62.6)	45 (71.4)	16 (88.9)	
Brachial region	80 (22.3)	11 (19.0)	53 (24.2)	15 (23.8)	1 (5.6)	0.079
Over the foot	31 (8.7)	3 (5.2)	26 (11.9)	1 (1.6)	1 (5.6)	
Other	5 (1.4)	0 (0.0)	3 (1.4)	2 (3.2)	0 (0.0)	
Initiative number of PVA. n (%)						
1	289(80.7)	49 (84.5)	174 (79.5)	54 (85.7)	12 (66.7)	
2	53 (14.8)	7 (12.1)	33 (15.1)	8 (12.7)	5 (27.8)	0.596
3	13 (3.6)	2 (3.4)	10 (4.6)	0 (0.0)	1 (5.6)	
4	3 (0.8)	0 (0.0)	2 (0.9)	1 (1.6)	0 (0.0)	

(PVA: Peripheral Vascular Access)

Table 6. Evaluation of premedication approaches in groups

	Total n=358	Group 1 n=58 No maintenance anesthesia	Group 2 n=219 Maintenance with inhalation anesthesia	Group 3 n=63 Maintenance with IV anesthesia	Group 4 n=18 Maintenance with inhalation and IV anesthesia	P
Premedication. n (%)						
Yes	168 (46.9)	41 (70.7)	72 (32.9)	45 (71.4)	10 (55.6)	<0.001
No	190 (53.1)	17 (29.3)	147 (67.1)	18 (28.6)	8 (44.4)	
Premedication application pathway. n (%)						
No	190 (53.1)	17 (29.3)	147 (67.1)		8 (44.4)	
PO	11 (3.1)	3 (5.2)	3 (1.4)	18 (28.6)	1 (5.6)	**<0.001**
IV	155 (43.3)	36 (62.1)	69 (31.5)	4 (6.3)	9 (50.0)	
IM	2 (0.6)	2 (3.4)	0 (0.0)	41 (65.1)	0 (0.0)	
				0 (0.0)		
Premedication Agent. n (%)						
No	190 (53.1)	17 (29.3)	147 (67.1)	18 (28.6)	8 (4.4)	
Midazolam	166 (46.4)	39 (67.2)	72 (32.9)	45 (71.4)	10 (55.6)	<0.001
Ketamin	2 (0.6)	2 (3.4)	0 (0.0)	0 (0.0)	0 (0.0)	

(PO: peroral. IV: intravenous. IM: intramuscular)

Table 7. Airway and anesthesia management of the groups

	Total n=358	Group 1 n=58 No maintenance anesthesia	Group 2 n=219 Maintenance with inhalation anesthesia	Group 3 n=63 Maintenance with IV anesthesia	Group 4 n=18 Maintenance with inhalation and IV anesthesia	P
Type of anesthesia induction. n (%)						
Inhale	80 (22.3)	1 (1.7)	69 (31.5)	3 (4.8)	7 (38.9)	**<0.001**
Propofol	231 (64.5)	35 (60.3)	145 (66.2)	40 (63.5)	11 (61.1)	
Ketamin	1 (0.3)	1 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)	
Ketamin + Propofol	41 (11.5)	16 (27.6)	5 (2.3)	20 (31.7)	0 (0.0)	
No induction	5 (1.4)	5 (8.6)	0 (0.0)	0 (0.0)	0 (0.0)	
Anesthesia maintenance airway equipment. n (%)						
Nasal Cannula	16 (4.5)	12 (20.7)	1 (0.5)	3 (4.8)	0 (0.0)	**<0.001**
Airway and simple face mask	283 (79.1)	30 (51.7)	195 (89.0)	43 (68.3)	15 (83.3)	
LMA	7 (2.0)	0 (0.0)	5 (2.3)	0 (0.0)	2 (11.1)	
Just a simple face mask	52 (14.5)	16 (27.6)	18 (8.2)	17 (27.0)	1 (5.6)	
Breathing pattern under anesthesia. n (%)						
spontaneous respiration	351 (98.0)	58 (100.0)	214 (97.7)	63 (100.0)	16 (88.9)	**0.015**
controlled breathing	7 (2.0)	0 (0.0)	5 (2.3)	0 (0.0)	2 (11.1)	

(LMA: Laringeal Mask Airway)

Table 8. MRI scan time and length of stay in MRI room

	Total n=358	Group 1 n=58 No maintenance anesthesia	Group 2 n=219 Maintenance with inhalation anesthesia	Group 3 n=63 Maintenance with IV anesthesia	Group 4 n=18 Maintenance with inhalation and IV anesthesia	P
MRI scan time	15.0 (10.0-20.0 [7.0-105.0])	10.0 (10.0-13.25 [7.0-30.0])	15.0 (10.0-20.0 [7.0-105.0])	16.0 (15.0-30.0 [9.0-68.0])	18.0 (13.5-20.5 [10.0-65.00])	**<0.001**
Length of stay in MRI room	20.0 (15.0-30.0 [10.0-110.0])	15.0 (14.0-20.0 [10.0-42.0])	20.0 (16.5-30.0 [12.0-110.0])	25.0 (20.0-40.0 [14.0-78.0])	24.5 (19.0-35.0 [15.0-80.0])	**<0.001**

MRI: Magnetic resonance imaging

Table 9. Complications during and after MRI

		Total n=358 No maintenance anesthesia	Group 1 n=58 Maintenance with inhalation anesthesia	Group 2 n=219 Maintenance with IV anesthesia	Group 3 n=63 Maintenance with inhalation and IV anesthesia	Group 4 n=18	P
Awakening during MRI scan. n (%)		38 (10.6)	8 (13.8)	12 (5.5)	14 (22.2)	4 (22.2)	<0.001
During and after MRI scan complications. n (%)		38 (10.6)	3 (5.2)	21 (9.6)	9 (14.3)	5 (27.8)	0.036
Desaturation		14 (3.9)	2 (3.4)	4 (1.8)	5 (7.9)	3 (16.6)	<0.001
Total n=14	**No intervention**	2 (14.2)	0 (0.0)	1 (25.0)	1 (20.0)	0 (0.0)	0.246
	Chin lift	5 (35.7)	0 0.0)	1 (25.0)	2 (40.0)	2 (66.6)	
	Airway	3 (21.4)	2 (100.0)	0 (0.0)	1 (20.0)	0 0.0)	
	PPV	4 (28.4)	0 (0.0)	2 (50.0)	1 (20.0)	1 (3.3)	
Laryngospasm		10 (2.8)	0 (0.0)	7 (3.2)	3 (4.8)	0 (0.0)	0.360
Bradycardia		11 (3.1)	0 (0.0)	8 (3.7)	2 (3.2)	1 (5.6)	0.482
Vomiting		2 (0.6)	0 (0.0)	2 (0.9)	0 (0.0)	0 (0.0)	0.735
Emergence delirium		3 (0.8)	0 (0.0)	3 (1.4)	0 (0.0)	0 (0.0)	0.589
Delayed complication		16 (4.5)	2 (3.4)	3 (1.4)	6 (9.5)	5 (27.8)	<0.001

(PPV: Positive Pressure Ventilation)

Premedication was not administered to 190 children (53.1%). Premedication was most commonly administered in Group 3 (71.4%). with IV being the most common route of administration (in 65.1% of cases) and midazolam being the most commonly administered agent (in 71.4% of cases) (p<0.001) (Table 6).

Anesthetic induction using IV propofol was most commonly performed in Group 2 (64.5%). The second most common means of induction was through the use of inhalational agents (22.3% of cases) (Table 7).

In terms of airway management. spontaneous breathing was the most common method during MRI under anesthesia in children (351/358; 98%); only seven patients were required general anesthesia using controlled breathing with laryngeal mask airway (LMA). which occurred most frequently in Group 4. The most commonly used airway equipment in anesthetized patients under spontaneous breathing was an airway and simple face mask (79.1%) (Table 7).

The mean MRI acquisition time was 15 (10.0–20.0 [7.0–105.0]) minutes. with the longest duration observed in Group 4 (p<0.001). However. the mean total time spent in the MRI room from the induction of anesthesia to awakening was 20 (15.0–30.0 [10.0-110.0]) minutes. with significantly lower times observed in Group 1 (p<0.001). (Table 8).

The frequency of awakening during MRI significantly differed between the groups and was most common in Groups 3 and 4; however. no significant difference was observed between those two groups (p>0.05).

During MRI. complications developed in 10.6% of cases. with the most and least frequent complications occurring in Groups 4 and 1. respectively. The most common complication was desaturation (3.9%). and the most commonly used interventional method in such patients was the chin-lift maneuver (35.7%). One patient exhibited an allergic reaction following contrast material administration and was treated with IV antihistamines. One patient experienced an epileptic attack and was treated with IV propofol; upon termination of seizure activity and stabilization. the procedure was resumed. and the patient was hospitalized in the pediatric neurology clinic. One patient in Group 2 experienced severe laryngospasm. and the MRI was terminated after it was determined that the cause was an upper respiratory tract infection (Table 9).

DISCUSSION

This study compared the efficacy and safety of different anesthesia maintenance methods during MRI in children. In our hospital. the most commonly used technique for anesthesia during MRI in pediatric patients was sevoflurane insufflation with an airway and simple face mask. and the fewest complications occurred in those who received sevoflurane inhalational anesthesia. suggesting that is the safest and most effective technique for pediatric patients undergoing MRI under anesthesia.

Because MRI does not involve radiation. it is preferred over other imaging techniques for diagnosis and treatment follow-up in children. In this patient population. however. anesthesia is often required to ensure absolute immobility during imaging and to alleviate anxiety caused by prolonged confinement.[1] Pediatric anesthesia is a specialized field owing to the many anatomical. airway. and physiological differences between infants. children. and adults.[7] In addition. anesthesia applications during MRI require additional experience because of the comorbidities frequently observed in children who require such imaging. the fact that only MRI-compatible devices can be used. and properties related to the structure of the MRI device and the room in which it is situated.

Children requiring MRI frequently have comorbidities such as neurological disorders. vascular malformations. and oncological tumors.[8] Although MRI has certain advantages over other imaging techniques. such as high image quality. superiority in revealing pathology. and the absence of radiation. the fact that it frequently requires anesthesia can result in short- and long-term risks related to the agents used for induction or maintenance. Contrary to what has been reported in the literature. this study demonstrated that the majority of the patients had an ASA 1 physical status classification. possibly due to the increasing frequency of usage and the wider range of indications that have emerged in recent years. However. for the aforementioned reasons. it is believed that MRI should be used more selectively. especially in children.

Many different techniques for sedation and general anesthesia can be applied during MRI. and many studies have been conducted to determine the optimal methodology. For example. Schulte-Uentrop and Goepfert[8] reported that sedation was preferred over general anesthesia in children without comorbidities. In contrast. however. Malviya et al.[9] suggested that general anesthesia during MRI in children can induce greater immobility and less hypoxemia than sedation. Inhalational agents such as sevoflurane. IV anesthetic agents such as propofol. ketamine. dexmedetomidine. midazolam. and pentobarbital. or different combinations of these agents can be used during these procedures.[10,11] Briggs et al.[12] argued in favor of sevoflurane as the ideal anesthetic agent for MRI in children for both induction and maintenance. Bryan et al.[13] found no difference in terms of respiratory complications in a study comparing sevoflurane and propofol administration. although a higher MRI success rate was observed with sevoflurane anesthesia. and Tahsin et al.[14] showed that the recovery time of pediatric MRI cases performed using sevoflurane was shorter than that of procedures performed using IV anesthetic agents such as propofol. ketamine. and dexmedetomidine. Although it has been shown that the use of sevoflurane in anesthesia management in pediatric patients may be associated with emergence delirium.[15] the present study failed to detect a significant difference in the frequency of this complication between patients in who did and did not receive sevoflurane for anesthesia management. In this study. sedation was selected more frequently than general anesthesia. IV propofol was most commonly used for anesthesia induction. and the sevoflurane insufflation technique was most commonly used for anesthesia maintenance; such preferences are likely related to the belief that these methods are the most effective for MRI under anesthesia. while simultaneously aiming to promote the fastest recovery. as these are generally outpatient or ambulatory procedures.

Recent studies have revealed that repeated or prolonged exposure to anesthetic drugs. especially up to the age of three years. may adversely affect neurodevelopment in children.[16] Therefore. many new non-anesthetic procedures have been proposed to facilitate MRI applications in children. such as having them watch movies. listen to music. and perform relaxation techniques or engage in play therapies. along with family training. Additionally. MRI-compatible equipment that allows for feeding and sleeping during procedures or promotes immobilization has been used successfully in infants.[16,17] For example. Barkovich et al.[18] recommended that the feeding and swaddling method should be prioritized for MRI in children younger than three months of age. In our hospital. unanesthetized MRI methods in children have been attempted only in older individuals in the form of suggestions; however only one 12-year-old has been persuaded. which allowed for the successful completion of the MRI procedure. It is likely that the low success rate is attributable to the large number of patients resulting in time-related limitations. the lack of experience among staff. and the lack of MRI-compatible devices for listening to music and watching movies. In our hospital. the only devices used for this purpose are headphones to prevent exposure to loud noises; however. some studies have shown that the use of headphones under anesthesia for this purpose can also decrease spontaneous arm–leg mobility.[19]

A review of the literature revealed that the most common cause of failure during MRI is patient mobility. with the most important contributor being the inadequate depth of anesthesia in children undergoing MRI.[20] Inadequate anesthesia may adversely impact MRI quality. prolong the working time of staff. increase costs associated with repeated imaging. and enhance anxiety in patients and their family members. In this study. awakening during MRI occurred most commonly in cases in which anesthesia maintenance was performed solely with IV anesthetics or with IV anesthetic agents in combination with inhalational anesthesia; these instances of awakening are likely attributable to the fact that IV anesthetics were administered via intermittent boluses rather than through continuous perfusion.

Although serious complications related to anesthesia for MRI in children such as cardiac arrest are rare. minor unwanted

complications such as laryngospasm. desaturation. vomiting. and allergies may be frequently encountered.[21] These minor adverse complications may become life-threatening if not managed correctly by taking necessary precautions. No serious complications such as cardiac or respiratory arrest were observed in the present study. and the most common complication was desaturation. with the chin-lift maneuver often serving as a sufficient intervention. It is believed that these complications would be encountered less frequently when anesthetic procedures outside the operating room are performed by healthcare personnel who are experienced in both anesthesia and pediatrics.

Limitations

The limitations of this study are that it was retrospective in nature. and anesthesia induction and maintenance were performed using different agents and by different anesthesiologists. However. one of the aims in this study was to assess the management of MRI under anesthesia in children when performed by anesthesiologists with different levels of experience. Prospective studies with larger sample sizes are warranted.

CONCLUSION

Procedures requiring prolonged periods of immobilization. such as MRI. continue to be difficult to perform owing to practical difficulties in some populations. including in pediatric patients. Outpatient or ambulatory anesthesia is currently considered the most effective and comfortable method for optimizing image quality and ensuring rapid recovery. However. it is important to minimize the associated risks while simultaneously ensuring an adequate depth of anesthesia. Ultimately. the results of this study suggest that sevoflurane insufflation with the preservation of spontaneous respiration is an effective and safe method for pediatric patients undergoing MRI under anesthesia.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the University of Health Sciences. Gülhane Clinical Researches Ethics Committee (Date: 10.09.2024. Decision No: 2024/441).

Informed Consent

Because the study was designed retrospectively. no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design. execution. and analysis of the paper. and that they have approved the final version.

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The role of nuclear medicine techniques; Tc-99m-labeled dimercaptosuccinic acid, diethylenetriaminepentaacetic acid, and mercaptoacetyltriglycine scintigraphies in pediatric surgery

Fatih Batı[1], Nilüfer Bıçakcı[2], Banu Kırtıloğlu[2], Behiye Atmaca Sağlık[2], Güler Silov[1]

[1]Department of Nuclear Medicine, Faculty of Medicine, Samsun University, Samsun, Turkiye
[2]Department of Nuclear Medicine, Samsun Training and Research Hospital, Samsun, Turkiye

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Corresponding Author: Fatih Batı, drfatihbati@gmail.com

ABSTRACT

The purpose of this review is to highlight the pivotal role of nuclear medicine in pediatric surgery, specifically in the diagnosis and management of nephro-urological conditions. This review focuses on the applications and advantages of three key nuclear medicine techniques: Tc-99m dimercaptosuccinic acid (DMSA), Tc-99m diethylenetriaminepentaacetic acid (DTPA), and Tc-99m mercaptoacetyltriglycine (MAG3) scintigraphies. These imaging modalities are crucial for providing detailed anatomical and functional information with minimal invasiveness, essential for evaluating congenital anomalies, urinary tract infections, and obstructive uropathies in children. DMSA Scintigraphy is established as the gold standard for detecting renal cortical scarring and assessing functional renal parenchymal damage. It offers superior sensitivity and specificity compared to other imaging techniques, making it indispensable for identifying renal scars from recurrent urinary tract infections or pyelonephritis. DTPA Scintigraphy is critical for measuring glomerular filtration rate (GFR) and analyzing renogram curves, providing quantitative assessments of renal function. It effectively evaluates renal perfusion and identifies perfusion defects and renal ischemia, essential for managing conditions like renal artery stenosis and unilateral kidney disease. MAG3 Scintigraphy excels in dynamic renal scintigraphy, particularly in patients with impaired renal function. It provides high-quality images and superior diagnostic capability, making it invaluable for assessing ureteropelvic junction obstruction and other obstructive uropathies in pediatric patients. The review concludes by emphasizing the integration of these scintigraphy techniques with SPECT/CT, enhancing diagnostic accuracy and providing comprehensive anatomical and functional insights. Despite concerns regarding radiation exposure, measures such as dose optimization and advanced imaging techniques ensure safety and efficacy in pediatric applications.

Keywords: Kidney diseases, radionuclide imaging, technetium Tc-99m dimercaptosuccinic acid, technetium Tc-99m diethylenetriaminepentaacetic acid

INTRODUCTION

Nuclear medicine plays a crucial role in pediatric surgery, particularly in the diagnosis and management of nephro-urological conditions. These conditions often require precise and accurate diagnostic tools to ensure effective treatment and management. Common conditions in pediatrics include congenital anomalies, urinary tract infections, and obstructive uropathies, among others.[1] Techniques such as Tc-99m dimercaptosuccinic acid (DMSA), Tc-99m diethylenetriaminepentaacetic acid (DTPA), and Tc-99m mercaptoacetyltriglycine (MAG3) scintigraphies are widely used due to their ability to provide detailed anatomical and functional information with minimal invasiveness. These tools are essential for the thorough evaluation and management of pediatric kidney diseases.[2,3]

DIMERCAPTOSUCCINIC ACID (DMSA) SCINTIGRAPHY

Indications and Use

Dimercaptosuccinic acid (DMSA) scintigraphy is primarily used in pediatric nephro-urological conditions for the detection of renal cortical scarring and functional renal parenchymal damage. This imaging technique is considered

the gold standard for evaluating renal parenchymal defects and is widely employed due to its high sensitivity and specificity.

1. **Detection of renal cortical scarring:** DMSA scintigraphy is highly effective in identifying renal cortical scars, which are often a result of recurrent urinary tract infections (UTIs) or pyelonephritis. Recent clinical research on acute pyelonephritis in children has shown that a significant portion (50%-91%) of those with febrile tract infections exhibit abnormal findings on DMSA scintigraphy. Furthermore, it was discovered that the majority of these children do not have detectable vesicoureteral reflux. However, when vesicoureteral reflux is present, DMSA scintigraphy reveals renal cortical abnormalities in 79-86% of the affected kidneys.[4] These scars indicate chronic kidney damage and can significantly impact renal function. Studies have shown that DMSA scintigraphy is superior to ultrasound in detecting these defects, with ultrasound having a sensitivity of only 36% compared to 96% specificity.[5]
2. **Assessment of functional renal parenchymal damage:** DMSA scans provide detailed images of the renal cortex, allowing for the assessment of functional renal parenchymal damage. This is crucial for diagnosing conditions such as renal dysplasia and for evaluating the extent of kidney damage after acute infections. The imaging technique helps in identifying focal and global defects in renal parenchyma, aiding in the management and treatment planning for affected children. [2]
3. **Comparison with other imaging modalities:** While newer imaging technologies, such as shear wave elastography (SWE) and unenhanced MRI, are being explored for similar purposes, DMSA scintigraphy remains the preferred method due to its established accuracy and reliability. Studies comparing SWE and DMSA have found that elastography does not yet match the performance of DMSA in predicting renal scarring.[6] Unenhanced MRI has shown promise as a non-radiative alternative, with high sensitivity and specificity for detecting renal scars in older children.[7]

Advantages of DMSA Scintigraphy

Dimercaptosuccinic acid (DMSA) scintigraphy is considered the gold standard for certain renal evaluations in pediatric nephro-urological conditions due to several key advantages:

1. **High sensitivity and specificity**: DMSA scintigraphy has a high sensitivity and specificity for detecting renal parenchymal defects and cortical scarring. Studies have shown that DMSA scintigraphy is significantly more sensitive than ultrasound (US) for identifying renal scars. For example, DMSA scintigraphy detected renal parenchymal defects in 31% of renal units compared to only 14% detected by US, highlighting its superior diagnostic accuracy.[5]
2. **Detailed renal cortical imaging**: DMSA scans provide detailed images of the renal cortex, allowing for precise identification of focal and global renal parenchymal defects. This is essential for diagnosing conditions such as renal scarring from recurrent urinary tract infections (UTIs) and pyelonephritis, enabling targeted and effective treatment plans.[2]
3. **Non-invasive and safe**: DMSA scintigraphy is a non-invasive procedure that involves minimal radiation exposure, making it safe for use in children. It offers a reliable and repeatable method for monitoring renal function and scarring over time without the need for more invasive diagnostic procedures.[8,9]
4. **Early detection and monitoring**: DMSA scintigraphy is effective in the early detection of renal scarring, which is crucial for preventing long-term kidney damage. It can also be used to monitor the progression or resolution of renal scarring in follow-up studies, providing valuable information for ongoing patient management.[10]
5. **Correlation with vesicoureteral reflux (VUR)**: DMSA scintigraphy is particularly useful in patients with vesicoureteral reflux (VUR). It provides detailed information on renal damage, correlating with the severity of VUR and helping to guide clinical management.[11,12] Even in cases of low-grade VUR, which might not be expected to cause significant damage, DMSA can detect early renal parenchymal injuries.[13]

DIETHYLENETRIAMINE PENTAACETIC ACID (DTPA) SCINTIGRAPHY

Indications and Use

Diethylenetriamine pentaacetic acid (DTPA) scintigraphy is widely used in assessing renal function due to its ability to measure glomerular filtration rate (GFR) and analyze renogram curves.

1. **Assessment of glomerular filtration rate (GFR)**: DTPA scintigraphy involves the use of technetium-99m labeled DTPA (Tc-99m DTPA), which is filtered exclusively by the glomeruli without any tubular reabsorption or secretion.[14] This makes it an ideal tracer for measuring GFR. The GFR is a crucial indicator of renal function, and DTPA scintigraphy provides an accurate and non-invasive method for its assessment.[15–17]
2. **Renogram curve analysis**: The renogram curve obtained from DTPA scintigraphy provides essential information about renal perfusion, function, and drainage. The analysis of this curve helps in diagnosing and monitoring various renal conditions such as obstructive uropathy, renal artery stenosis, and differential renal function in cases of unilateral kidney disease.[18]

Advantages

DTPA scintigraphy has several advantages in evaluating renal perfusion and function:

1. **Effectiveness in evaluating renal perfusion**: DTPA scintigraphy provides detailed information on renal blood flow and perfusion, which is critical for assessing the functional status of the kidneys. It helps in identifying perfusion defects and evaluating the

extent of renal ischemia, which is particularly useful in patients with conditions such as renal artery stenosis and post-surgical evaluations.[19]

2. **Quantitative analysis of renal function**: DTPA scintigraphy allows for the quantitative measurement of GFR, providing precise and reliable data that can be used to monitor renal function over time. This quantitative capability is essential for assessing the impact of various interventions and treatments on renal function and for early detection of renal dysfunction.[15]
3. **Non-invasive and safe**: As a non-invasive procedure, DTPA scintigraphy involves minimal discomfort and risk to the patient. It is particularly advantageous for pediatric and geriatric populations, where invasive procedures may pose significant risks. The procedure involves a small amount of radiation, which is generally well-tolerated and considered safe for routine clinical use.[14,18,20]

MERCAPTOACETYLTRIGLYCİINE (MAG3) SCINTIGRAPHY

Indications and Use

Mercaptoacetyltriglycine (MAG3) scintigraphy is widely used in dynamic renal scintigraphy, especially in cases of impaired renal function. It provides detailed information on renal perfusion, function, and drainage.

1. **Dynamic renal scintigraphy**: MAG3 is used in dynamic renal scintigraphy to assess renal perfusion and function. It is particularly useful for evaluating patients with impaired renal function due to its ability to provide clear images even when renal function is reduced. MAG3 scintigraphy helps in diagnosing and managing various renal conditions, including obstructive uropathies, renovascular hypertension, and differential renal function in patients with unilateral kidney disease.[2,21,22]
2. **Evaluating pediatric ureteropelvic junction obstruction (UPJO)**: MAG3 scintigraphy is commonly used to evaluate ureteropelvic junction obstruction (UPJO) in children. It helps in assessing the severity of obstruction and the functional status of the kidneys, which is critical for determining the appropriate surgical intervention. Studies have shown that MAG3 scintigraphy provides reliable measurements of split renal function, making it a valuable tool in the preoperative evaluation of UPJO.[23–25]

Advantages

MAG3 scintigraphy offers several advantages in evaluating renal function, particularly in pediatric patients:

1. **Superior image quality**: MAG3 provides superior image quality compared to other radiotracers like DTPA, especially in patients with impaired renal function. This is due to its higher extraction efficiency, which results in clearer and more detailed images of renal perfusion and function. This makes MAG3 scintigraphy particularly useful in pediatric assessments, where accurate imaging is crucial for diagnosis and treatment planning.[26]
2. **Diagnostic capability**: MAG3 scintigraphy is highly effective in diagnosing and monitoring renal conditions. It provides comprehensive information about renal perfusion, drainage, and function, which is essential for managing conditions such as obstructive uropathies, congenital anomalies, and renovascular diseases. Its ability to accurately measure split renal function is particularly beneficial in evaluating pediatric patients with complex renal conditions.[2]
3. **Non-invasive and safe**: MAG3 scintigraphy is a non-invasive procedure that involves minimal risk to the patient. It is particularly advantageous for pediatric patients, as it does not require sedation and has a low radiation dose. This makes it a safe and effective method for repeated evaluations, allowing for continuous monitoring of renal function over time.[23]

Clinical Applications in Pediatric Surgery

- **Diagnosis of Renal Conditions**
- **Renal Scarring and Cortical Damage**

Dimercaptosuccinic acid (DMSA) scintigraphy is extensively used for identifying renal scars and cortical defects in pediatric patients. DMSA scans are particularly valuable in detecting renal cortical scarring, which often results from acute pyelonephritis (APN) and recurrent urinary tract infections (UTIs). This imaging technique provides high-resolution images of the renal cortex, making it the gold standard for identifying and assessing the extent of renal scarring and cortical damage.[27,28]

1. **Identifying renal scars**: DMSA scintigraphy is highly sensitive in detecting renal scars. Studies show that late DMSA scans (conducted six months post-infection) are effective in predicting vesicoureteral reflux (VUR) and long-lasting renal scars in children with first-time acute pyelonephritis. The presence of cortical defects on these scans indicates a higher risk of VUR and recurrent UTIs, making DMSA an essential tool for long-term renal health monitoring.[29]
2. **Evaluating cortical damage**: DMSA scans are critical for evaluating the extent of cortical damage following acute pyelonephritis. The scan's ability to detect permanent renal scarring aids in managing and predicting long-term outcomes for pediatric patients. Factors such as the presence and grade of VUR, as well as the age at diagnosis, significantly influence the likelihood of developing renal scars.[30]

- **Functional Renal Assessment**

Diethylenetriamine pentaacetic acid (DTPA) and mercaptoacetyltriglycine (MAG3) scintigraphy are crucial in evaluating renal function and detecting vesicoureteral reflux (VUR).

1. **DTPA scintigraphy**: DTPA scintigraphy is used to assess glomerular filtration rate (GFR) and renal function. This imaging technique is beneficial in

cases of impaired renal function, providing detailed information about renal perfusion and function. DTPA scans help in the early detection and monitoring of renal dysfunction, offering precise quantitative measurements of GFR, which are essential for managing chronic kidney disease and other renal conditions.[15]

2. **MAG3 scintigraphy**: MAG3 scintigraphy is preferred for its superior image quality and diagnostic capability, particularly in pediatric renal assessments. This technique is highly effective in evaluating renal perfusion and function, making it ideal for detecting VUR and other renal conditions. MAG3 scans provide detailed dynamic images, allowing for accurate measurement of renal function and detection of urinary tract obstructions and other anomalies. The high extraction efficiency of MAG3 ensures clearer and more reliable images, even in cases of impaired renal function.[22,26]

Management and Follow-Up

- **Congenital Anomalies and Urinary Infections**
- **Initial Diagnosis and Follow-Up**

1. **Dimercaptosuccinic acid (DMSA) scintigraphy**: DMSA scintigraphy is a critical tool for the initial diagnosis and follow-up of congenital renal anomalies and recurrent urinary infections. It is highly effective in identifying renal scars and cortical defects caused by urinary tract infections (UTIs). This technique is particularly valuable in diagnosing acute pyelonephritis (APN) and assessing long-term renal damage. Studies have shown that DMSA scans can confirm the presence of renal scars in a significant number of children with UTIs, helping to localize parenchymal changes and guide management strategies.[28,31,32]
2. **Diethylenetriamine pentaacetic acid (DTPA) and mercaptoacetyltriglycine (MAG3) scintigraphy**: Both DTPA and MAG3 scintigraphy are used for functional renal assessment. These techniques help in evaluating renal perfusion and function, providing detailed images that aid in diagnosing and monitoring congenital renal anomalies. They are particularly useful in cases of vesicoureteral reflux (VUR) and other urinary tract obstructions (Figure 1.). Dynamic renal scintigraphy with MAG3 is noted for its superior image quality and diagnostic accuracy, making it ideal for pediatric patients.[33]

- **Surgical Planning and Postoperative Care**

1. **Role in surgical planning**: Nuclear medicine techniques such as DTPA and MAG3 scintigraphy are essential in the preoperative evaluation and planning of surgeries involving renal anomalies and obstructions.[34–36] These imaging modalities provide crucial information on renal function and perfusion, allowing surgeons to assess the extent of the condition and plan the appropriate surgical intervention. For instance, MAG3 scintigraphy is used to evaluate the function of the renal units before corrective surgeries for ureteropelvic junction obstruction (UPJO), helping to determine the necessity and type of surgical intervention.[36,37]
2. **Monitoring post-surgery outcomes**: Postoperative care and monitoring of renal function are critical to ensuring successful surgical outcomes. DMSA, DTPA, and MAG3 scintigraphy are used to monitor the function and recovery of the kidneys after surgery. These techniques help in detecting any complications, such as recurrent obstructions or renal scarring, allowing for timely interventions and adjustments in the treatment plan. Continuous monitoring with these imaging modalities ensures that the kidneys are functioning optimally and helps in managing any long-term sequelae of the surgical procedures.[38]

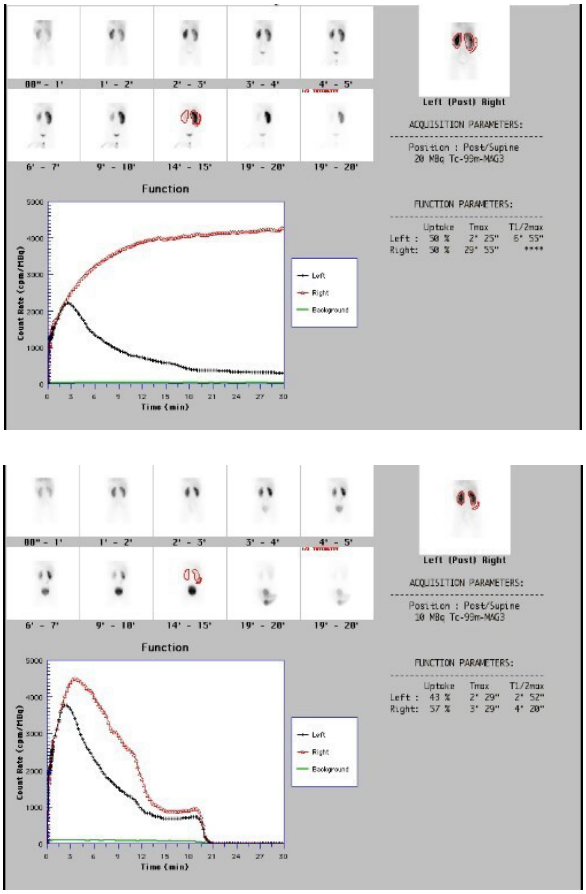

Figure 1. Roi curve showing the functional change after imaging with MAG3 scintigraphy before and after surgery in a 4-year-old girl diagnosed with vesicoureteral reflux. Image on the left before surgery, image on the right after surgery (from the archive of Prof. Dr. Ünal Bıçakcı; Ondokuz Mayıs University Faculty of Medicine Department of Pediatric Surgery and Division of Pediatric Urology).

SPECT/CT INTEGRATION

Enhanced Imaging

The integration of single-photon emission computed tomography (SPECT) with computed tomography (CT) in dimercaptosuccinic acid (DMSA) scintigraphy significantly enhances diagnostic accuracy and reader confidence in pediatric renal assessments.

1. **Improved diagnostic accuracy**: SPECT/CT provides a hybrid imaging technique that combines functional and anatomical data, offering superior diagnostic capabilities compared to planar imaging alone. This integration allows for precise localization and characterization of renal lesions, improving the detection and evaluation of renal cortical defects and

scarring. For instance, a study on patients with sickle cell disease demonstrated that SPECT/CT with DMSA was more effective in identifying cortical lesions compared to planar imaging, with lesions clearly identified only on SPECT images in 52% of cases.

2. **Enhanced anatomical detail**: The combination of SPECT and CT provides detailed anatomical context to functional imaging, allowing for better differentiation between renal parenchymal abnormalities and other structures. This enhanced detail helps in accurately diagnosing conditions such as renal scars, infections, and other abnormalities. SPECT/CT has been shown to identify renal lesions, prominent renal columns, and increased renal size, offering comprehensive insights into renal morphology and function.[39]
3. **Increased reader confidence**: The integration of SPECT/CT improves reader confidence by providing clearer and more detailed images, reducing uncertainty in interpreting complex cases. The ability to visualize functional data in conjunction with high-resolution anatomical structures allows for more accurate and confident diagnoses. This is particularly beneficial in pediatric patients, where precise diagnosis is crucial for effective management and treatment planning. For example, SPECT/CT was found to enhance the interpretation of radionuclide shunt studies by clearly demonstrating activity accumulation and identifying obstructions that were not evident on planar images alone.[40]

Limitations and Considerations

Radiation Exposure

Concerns related to radiation exposure: Radiation exposure is a significant concern in pediatric patients undergoing scintigraphy due to their increased sensitivity to radiation and the potential long-term risks associated with cumulative exposure. Minimizing radiation dose is crucial to reduce the risk of radiation-induced damage, especially in young children whose tissues and organs are more susceptible to radiation.

Measures to Minimize Radiation Exposure

1. **Dose optimization:** Using the lowest effective dose of radiopharmaceuticals is essential. Pediatric radiopharmaceutical doses are often calculated based on body weight or surface area to ensure that the radiation dose is as low as reasonably achievable (ALARA) while still obtaining diagnostic quality images.[2]
2. **Advanced imaging techniques:** Incorporating advanced imaging techniques such as SPECT/CT can enhance diagnostic accuracy, potentially reducing the need for repeat scans. The combined functional and anatomical imaging provided by SPECT/CT allows for more precise localization and characterization of renal lesions, thereby improving diagnostic confidence and reducing unnecessary additional imaging.[39]
3. **Shielding and protective measures:** Implementing appropriate shielding and protective measures during imaging procedures can further minimize radiation exposure to non-targeted areas of the body. Ensuring that only the area of interest is exposed to radiation and using lead aprons or other protective devices can help protect other body parts from unnecessary radiation.[41]

Future Directions and Research

Technological Advancements

Potential advancements in nuclear medicine:

1. **Hybrid imaging techniques:** The integration of SPECT/CT and PET/MRI is expected to enhance the diagnostic accuracy and detail of pediatric renal imaging. These hybrid modalities provide comprehensive functional and anatomical information, facilitating more precise diagnoses and treatment plans. The use of PET/MRI, although currently less common, offers significant potential due to its superior soft-tissue contrast and lower radiation dose compared to PET/CT.[42]
2. **Artificial intelligence and machine learning:** The integration of artificial intelligence (AI) and machine learning (ML) in nuclear medicine can revolutionize image analysis and interpretation. AI algorithms can assist in detecting subtle abnormalities, quantifying renal function, and predicting outcomes, thereby improving the accuracy and efficiency of diagnoses. These technologies also hold promise for personalized medicine by tailoring diagnostic and therapeutic approaches to individual patient profiles.[43]

New radiotracers and molecular imaging: The development of new radiotracers and molecular imaging agents can provide more specific and sensitive detection of renal pathologies. Targeted tracers designed for specific renal receptors or metabolic pathways can enhance the detection of early disease stages and monitor therapeutic responses more effectively. The concept of theranostics, combining diagnostic and therapeutic capabilities in a single agent, is also gaining traction, offering personalized treatment options.[44]

DISCUSSION

Nuclear medicine techniques such as Tc-99m DMSA, Tc-99m DTPA, and Tc-99m MAG3 scintigraphies play an indispensable role in pediatric nephro-urology, providing critical diagnostic and management tools. Each of these techniques offers unique advantages and comes with certain limitations, making it important to choose the appropriate modality based on the clinical scenario.

Advantages and Disadvantages of DMSA Scintigraphy

Advantages

1. **High sensitivity and specificity:** DMSA scintigraphy is the gold standard for detecting renal cortical scarring and assessing functional renal parenchymal damage. It surpasses ultrasound in sensitivity and specificity, making it indispensable for early detection and monitoring of renal scars resulting from recurrent UTIs or pyelonephritis.[5]

2. **Detailed renal cortical imaging**: The high-resolution images provided by DMSA scans allow for precise identification of focal and global renal parenchymal defects, which is crucial for accurate diagnosis and effective treatment planning.[2]
3. **Non-invasive and safe:** DMSA scintigraphy is minimally invasive and involves low radiation exposure, making it a safe and repeatable method for pediatric patients.[8]

Disadvantages

1. **Radiation Exposure:** Despite being low, radiation exposure remains a concern, especially for repeated scans over time. Efforts must be made to minimize radiation dose while maintaining diagnostic accuracy.[45]
2. **Limited functional information:** While excellent for anatomical details, DMSA scintigraphy provides limited functional information compared to techniques like DTPA and MAG3, which can assess renal perfusion and function.[2]

Advantages and Disadvantages of DTPA Scintigraphy

Advantages

1. **Assessment of GFR:** DTPA scintigraphy is ideal for measuring GFR, providing quantitative data essential for diagnosing and monitoring renal conditions such as obstructive uropathy and renal artery stenosis.[15]
2. **Effective in evaluating renal perfusion:** DTPA scans offer detailed insights into renal blood flow and perfusion, helping to identify perfusion defects and renal ischemia.[19]
3. **Non-invasive and safe:** Similar to DMSA, DTPA scintigraphy is minimally invasive with low radiation exposure, making it suitable for pediatric use.[18]

Disadvantages

1. **Radiation exposure:** Although low, the cumulative radiation dose can be a concern, particularly in pediatric patients requiring multiple scans.[45]
2. **Less detailed anatomical imaging:** Compared to DMSA, DTPA provides less detailed anatomical information, which can be a limitation when precise localization of defects is needed.[2]

Advantages and Disadvantages of MAG3 Scintigraphy

Advantages

1. **Dynamic imaging capability:** MAG3 scintigraphy excels in dynamic renal imaging, particularly useful in assessing conditions like ureteropelvic junction obstruction (UPJO) and other obstructive uropathies.[23]
2. **Superior image quality:** MAG3 provides high-quality images even in patients with impaired renal function, due to its higher extraction efficiency, which results in clearer and more reliable images.[21]
3. **Non-invasive and safe:** MAG3 scintigraphy, like DMSA and DTPA, is non-invasive and involves low radiation exposure, making it safe for repeated evaluations.[23]

Disadvantages

1. **Radiation exposure:** Despite being low, the radiation dose must be carefully managed, especially in children who are more sensitive to radiation.[45]
2. **Availability and cost:** The advanced technology and radiotracers required for MAG3 scintigraphy can be more costly and less widely available compared to other techniques.[46]

CURRENT TRENDS AND FUTURE DIRECTIONS

Recent advancements in hybrid imaging techniques, such as the integration of SPECT/CT and PET/MRI, promise to enhance the diagnostic accuracy and detail of pediatric renal imaging by combining functional and anatomical data. This hybrid approach allows for precise localization and characterization of renal lesions, improving the overall diagnostic process. Additionally, the integration of artificial intelligence (AI) and machine learning (ML) in nuclear medicine can revolutionize image analysis and interpretation, leading to more accurate and efficient diagnoses.[42,43]

CONCLUSION

Nuclear medicine plays a crucial role in pediatric nephro-urology, offering essential diagnostic and management tools for various renal conditions. Techniques such as Tc-99m DMSA, Tc-99m DTPA, and Tc-99m MAG3 scintigraphies provide detailed anatomical and functional insights with minimal invasiveness, making them ideal for use in children.

DMSA Scintigraphy is highly sensitive and specific for detecting renal cortical scarring and parenchymal damage, crucial for managing recurrent UTIs and pyelonephritis. It remains the gold standard for evaluating renal defects, outperforming other imaging modalities like ultrasound.

DTPA Scintigraphy is valuable for assessing glomerular filtration rate (GFR) and renal perfusion. It provides quantitative data essential for diagnosing and monitoring renal conditions such as obstructive uropathy and renal artery stenosis.

MAG3 Scintigraphy excels in dynamic renal imaging, especially in cases of impaired renal function. It offers superior image quality and diagnostic capability, particularly for conditions like ureteropelvic junction obstruction (UPJO) in children.

The integration of SPECT/CT enhances diagnostic accuracy by combining functional and anatomical data, improving the detection and evaluation of renal defects and scarring.

While radiation exposure is a concern, measures like dose optimization, advanced imaging techniques, and protective measures help minimize risks, especially in pediatric patients.

Future advancements in nuclear medicine, such as hybrid imaging techniques, artificial intelligence, and new radiotracers, promise to further enhance diagnostic precision and treatment efficacy.

Contribution to the scientific community: This review underscores the indispensable role of nuclear medicine in

pediatric nephro-urology, highlighting the strengths and limitations of various scintigraphy techniques. By providing a comprehensive overview of the applications and advantages of Tc-99m DMSA, DTPA, and MAG3 scintigraphies, this paper aids clinicians in selecting the most appropriate diagnostic tool based on specific clinical scenarios. The discussion on recent technological advancements and future directions in nuclear medicine offers valuable insights for ongoing research and clinical practice, aiming to improve patient outcomes and quality of care in pediatric nephro-urology

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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Caudal analgesia application with bupivacaine in a pediatric patient with glucose-6-phosphate dehydrogenase enzyme deficiency: case report*

Mehmet Kara, Cevdet Yardımcı, Yeşim Andıran Şenaylı

Department of Anesthesiology and Reanimation, Faculty of Medicine, Yozgat Bozok University, Yozgat, Turkiye

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Corresponding Author: Cevdet Yardımcı, cevdetyardimci@hotmail.com

ABSTRACT

Glucose-6-phosphate dehydrogenase enzyme has a cells protecting feature from oxidative damage. Glucose-6-phosphate Dehydrogenase Enzyme Deficiency is a hereditary disease that causes hemolysis in cases of deficiency due to mutation in the X chromosome, due to oxidative stresses such as some drugs, chemicals or infection. The preoperative Hb of a 4-year-old patient who was to undergo circumcision surgery was determined as 8.9 g/dl. Since increased bleeding was not expected during this procedure, no attempt was made to increase the hemoglobin value. After the induction of general anesthesia with sevoflurane 8%, 1 ml/kg of 0.25% bupivacaine was administered caudally to the patient. The hemodynamic findings remained within normal limits during the surgical procedure. In the follow-up, it was determined that the pain score was low and that no additional analgesic drugs were required. Afterwards, no additional hematological abnormalities were detected and the patient was discharged two days later. We believe that during surgery, when routine monitoring measures are taken and conditions that may cause stress to the patient such as hypotension, hypoxemia, and dehydration are avoided, the patient's anesthesia and postoperative pain can be controlled with a general anesthetic gas such as sevoflurane and a local anesthetic such as bupivacaine, with attention to toxic doses.

Keywords: Bupivacaine, caudal analgesia, glucose-6-phosphate dehydrogenase deficiency, postoperative analgesia, sevorane

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INTRODUCTION

Glucose-6-phosphate dehydrogenase (G6PD) deficiency is one of the most common enzymopathies resulting from mutations in the G6PD gene linked to the X chromosome.[1]caused by inherited mutations of the X-linked gene G6PD. G6PD deficiency makes red cells highly vulnerable to oxidative damage, and therefore susceptible to hemolysis. Over 200 G6PD mutations are known: approximately one-half are polymorphic and therefore common in various populations. Some 500 million persons with any of these mutations are mostly asymptomatic throughout their lifetime; however, any of them may develop acute and sometimes very severe hemolytic anemia when triggered by ingestion of fava beans, by any of a number of drugs (for example, primaquine, rasburicase G6PD deficiency is typically inherited as an X-linked recessive trait, and is more common in males than females.[2] G6PD deficiency makes red blood cells highly vulnerable to oxidative damage, leading to sensitivity to hemolysis.[1]caused by inherited mutations of the X-linked gene G6PD. G6PD deficiency makes red cells highly vulnerable to oxidative damage, and therefore susceptible to hemolysis. Over 200 G6PD mutations are known: approximately one-half are polymorphic and therefore common in various populations. Some 500 million persons with any of these mutations are mostly asymptomatic throughout their lifetime; however, any of them may develop acute and sometimes very severe hemolytic anemia when triggered by ingestion of fava beans, by any of a number of drugs (for example, primaquine, rasburicase Many agents used in anesthesia can cause hemolysis in patients with G6PD deficiency.[3] In this case, we planned to present the anesthesia management of a pediatric patient with G6PD deficiency who underwent orchidopexy and circumcision surgery.

CASE

Orchiopexy and circumcision surgery was planned by the pediatric surgery clinicians for a 4-year-old male patient weighing 16 kilograms. Parents of the child expressed that

G6PD enzyme deficiency was diagnosed by the pediatric hematology clinicians at the age of 2 due to prolonged jaundice and the patient did not develop hemolytic crisis before or after this diagnosis. No pathological findings were detected in the patient's preoperative physical examination. Preoperative hemogram and biochemical values of the patient were observed as follows; hemoglobin (Hb): 8.9 g/dl, hematocrit (Hct): 28%, mean corpuscular volüme (MCV): 55.3 fL, erythrocyte: $5.06x10^6$/µL, platelet (Plt): $411x10^3$/µL, blood urea nitrogen (BUN): 20.76 mg/dl, serum creatinine (sCrea): 0.40 mg/dl, alanine aminotransferase (ALT): 10.2 IU/L, aspartate aminotransferase (AST): 26.9 IU/L, INR: 1,12.

After a 6-hour preoperative fasting period, the patient was taken to the operating room 25 minutes after premedication with 0.5 mg/kg (8 mg) oral midazolam. After routine ASA monitoring and induction of general anesthesia with sevoflurane, intravenous line was inserted with a 24 G intracath. Fluid replacement was obtained with this intravenous line. After intravenous administration of 1 µg/kg fentanyl and 2.5 mg/kg propofol, a laryngeal mask (LMA) was successfully placed on the first attempt. LMA's appropriate placement was confirmed by auscultation of both lungs which were sufficiently and equally ventilated. After sterile staining and draping, the caudal space was located. In the right lateral decubitus position, After confirmation of the caudal needle's correct placement, 1 ml/kg 0.25% bupivacaine was injected in the epidural space for analgesia. The patient was placed in the supine position again and surgery was started. Anesthesia was maintained with a mixture of 50% O_2 + 50% dried air and 2% sevoflurane. No muscle relaxant was used during induction and maintenance. During the operation, which lasted approximately 80 (eighty) minutes, no complications such as hypotension, hyperthermia, hematuria, which could be signs of hemolytic crisis, were observed and the patient did not require additional opioids. At the end of the operation, the laryngeal mask was removed without any problems when spontaneous breathing became adequate and regular. In the recovery unit, the patient, who did not have any hemodynamic or respiratory problems, was transferred to the pediatric surgery ward.

Twenty four hours after the operation, Hb: 8.6 g/dL, Hct: 27.2%, MCV: 55.3 Fl, erythrocyte: 4.95, ALT: 8.5 IU/L, AST: 21.2 IU/L, direct bilirubin: 0.243 mg/dl, total bilirubin: 0.835 mg/dl, BUN: 10.7 mg/dL, sCrea: 0.46 mg/dl values were observed. The patient, who did not have any problems during the follow-up in the ward, was discharged 2 days later.

DISCUSSION

G6PD deficiency is a very common disease in which a severe erythrocyte enzyme defect results in acute hemolysis after exposure to an oxidative stressor caused by a mutation linked to the X chromosome.[1]caused by inherited mutations of the X-linked gene G6PD. G6PD deficiency makes red cells highly vulnerable to oxidative damage, and therefore susceptible to hemolysis. Over 200 G6PD mutations are known: approximately one-half are polymorphic and therefore common in various populations. Some 500 million persons with any of these mutations are mostly asymptomatic throughout their lifetime; however, any of them may develop acute and sometimes very severe hemolytic anemia when triggered by ingestion of fava beans, by any of a number of drugs (for example, primaquine, rasburicase

The G6PD enzyme found in erythrocytes catalyzes the first step in the pentose monophosphate pathway of carbohydrate metabolism to protect the cell from oxidative damage. G6PD is involved in the production of nicotinamide adenine dinucleotide phosphate (NADPH), which is necessary to maintain normal intracellular glutathione levels. Glutathione is responsible for the destruction of oxidant substances formed in erythrocytes due to various external factors such as drugs, infections, and metabolic problems.[4]

The reason for hemolysis in G6PD deficiency is that erythrocytes cannot maintain glutathione in a reduced state when exposed to an oxidizing agent. The line of defense against oxidative stress is directly proportional to the current enzyme activation in the patient. While G6PD deficiency normally has little or no clinical effect, G6PD activity increases in oxidative stress situations and increases the cell's reducing capacity. Acute hemolysis may develop in people with G6PD deficiency because red blood cells cannot be protected from oxidant stress. While no clinical findings are observed in people with G6PD deficiency under normal conditions, acute hemolysis may occur in situations that cause oxidative stress, such as infection, metabolic problems and some medications.[5]diagnosis, and medication-use implications of glucose-6-phosphate dehydrogenase (G6PD

Avoidance of the situations that may lead to oxidative stress in G6PD deficiency is the basis of treatment. Therefore, pain that may cause acute stress in these patients must be well controlled perioperatively.[6]

Hemolysis is common in the first 3 days after surgery. The severity and duration of hemolysis vary among patients. The agent causing hemolysis should be removed from the body as quickly as possible. Acute hemolysis may be self-limiting or may cause symptoms such as headache, cyanosis, tachycardia, dyspnea, substernal or lumbar pain, fatigue, hemoglobinuria, jaundice, and scleral icterus. Hemoglobinuria may be the first finding in the intraoperative period. If hemolysis is mild, supportive treatment may be required, and in severe cases, severe hemolytic anemia may develop, rarely requiring erythrocyte replacement. Blood transfusion is generally recommended when Hb falls below 7 g/dl or if hemoglobinuria persists when Hb is between 7-9 g/dl.[7]with its severe sequelae of bilirubin neurotoxicity and the potential of death, is the most devastating manifestation of G6PD deficiency. In a recent review of Favism, Luzzatto and Arese state that the pathophysiology of jaundice in G6PD-deficient neonates is different from that of favism, as there is little evidence of hemolysis in these infants. Objectives: To explore the role of hemolysis in neonatal hyperbilirubinemia associated with G6PD deficiency. Methods: Previously published works including studies of endogenous production of carbon monoxide (CO Therefore, daily hemogram and urine should be monitored in patients receiving general anesthesia during the postoperative period.

Many agents used in anesthesia have been associated with acute hemolysis in individuals with G6PD deficiency. It has been suggested that anesthetic agents such as midazolam,

diazepam, ketamine, halothane, sevoflurane, and prilocaine have an effect on G6PD enzyme activity, and that especially sevoflurane, isoflurane, diazepam, and midazolam have an inhibitory effect, but it has been reported that further research is needed on the subject.[8]with an estimated 400 million people worldwide carrying a mutation in the G6PD gene that causes deficiency of the enzyme. Although drug-induced haemolysis is considered the most common adverse clinical consequence of G6PD deficiency, significant confusion exists regarding which drugs can cause haemolytic anaemia in patients with G6PD deficiency. In the absence of consensus among physicians, patients are subject to conflicting advice, causing uncertainty and distress. In the current review we aimed, by thorough search of the medical literature, to collect evidence on which to base decisions either to prohibit or allow the use of various medications in patients with G6PD deficiency. A literature search was conducted during May 2009 for studies and case reports on medication use and G6PD deficiency using the following sources: MEDLINE (1966May 2009 It has also been emphasized that when the use of these inhibitory agents is necessary, their side effects can be minimized by careful dose adjustment. Valiaveedan et al.[6] stated that all general anesthetic agents are generally safe and supported this in their study. In the literature, malignant hyperthermia has been reported in only one patient during the use of halothane due to the use of general anesthetic agents. In another case reported by Goi et al.[9], 3,5 ml of mepivacaine was used to a 3 year old boy necessitating dental therapy under general anesthesia. For this patient, also sevoflurane and rocuronium was used in the induction, and propofol and remifentanyl infusions were used during general anesthesia maintenance. Local anesthetic drugs such as prilocaine and lidocaine should be avoided in individuals with G6PD deficiency due to the risk of methemoglobinemia. Bupivacaine has been reported as a safe agent in G6PD deficiency.[9]

Takahashi et al.[10] reported anesthesia management of a 22 kg 5 year old boy in need of upper labial frenulum excision. They reported use of midazolam and dexmedetomidin infusion for sedation for 15 minutes duration of procedure and 1 ml of 2% lidocain for local anesthesia of the excision site. They reported no undesired side effect such as hemolytic crisis up to a week postoperatively.

In the postoperative period, reducing pain is important because it prevents oxidative stress and prevents hemolysis. Accordingly, agents containing antioxidant vitamins and minerals should be used in the preoperative period and pain should be reduced in the postoperative period. Adequate doses of paracetamol are generally recommended for postoperative pain in children, but there are some concerns about the safety of this drug in patients with G6PD deficiency and therefore it should be carefully evaluated for these patients. For this reason, paracetamol was not used in our patient. Regional anesthesia can be applied in children, but it is usually combined with general anesthesia or used for postoperative pain control.[11] We also applied the caudal analgesia technique in our patient for intraoperative analgesia and postoperative pain control. Successful postoperative analgesia was achieved in our patient whose Visual Analog Scale (VAS) value did not exceed 2 for 30 hours after surgery and who did not require additional analgesics.

In Gómez et al.'s[12] reported case, a 45 year old man with G6PD deficiency having laparoscopic low anterior rectal resection, general anesthesia management were performed with total intravenous anesthesia with propofol (2,5-3 mg/kg/h), rocuronium (50 mg), fentanyl 350 mcg in total, and 8 ml bupivacaine (0,125% in concentration) was used. And they reported no unfavorable effect.

There is ongoing debate about which medications are safe for people with G6PD. Our patient was restless and anxious preoperatively, so oral midazolam was administered before surgery. Sevoflurane was used for induction and maintenance, but it did not cause hemolysis and did not compromise the patient's stability. In order to reduce surgical stress and pain, our patient was provided with adequate pain management with the caudal analgesia technique. The lack of need for muscle relaxants with laryngeal mask application prevented the use of additional medications. No intraoperative or postoperative problems were experienced. We believe that the short duration of the operation and careful adjustment of the inhalation agent dosage contributed to this.

CONCLUSION

As a result, in patients diagnosed with G6PD deficiency who will undergo general anesthesia, the stress caused by surgery and anesthesia should be reduced, agents that may cause hemolytic crisis should be avoided, and a safe perioperative anesthesia plan should be made.

There are concerns about triggering hemolytic crisis with agents such as sevoflurane, isoflurane and midazolam in the performance of general anesthesia in patients with G6PD deficiency. Premedication with midazolam, induction of general anesthesia with sevoflurane + propofol, maintenance of general anesthesia with sevorlurane and caudal analgesia with bupivacaine, may be used with caution of local anesthetic toxic doses.

ETHICAL DECLARATIONS

Informed Consent

The patient signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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