

# Utilization trend of magnetic resonance imaging examinations in an academic emergency department and the weekend effect

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## Abstract

**Aim:** The utilization of magnetic resonance imaging in the emergency department is gradually increasing. An update is needed on how the use of magnetic resonance imaging exams in the emergency department has evolved. To reveal the magnetic resonance imaging utilization trends of the emergency department in the last five years (2015-2019) and whether the weekend effect affects the magnetic resonance imaging test requests of the emergency physician.

**Material and methods:** Emergency department-ordered magnetic resonance imaging examinations were obtained from the hospital's electronic database retrospectively. Magnetic resonance imaging were grouped as abdominopelvic, neuroimaging, musculoskeletal, and others.

**Results:** A total of 9870 magnetic resonance imaging examinations were performed in the 5 years. The rate of emergency department-ordered magnetic resonance imaging tests was 2.65%. Magnetic resonance imaging for neuroimaging, including brain and spinal examinations, was the most ordered examination, with a rate of 98.8%. The average time between imaging order and acquisition was 46 minutes. No significant difference between the magnetic resonance imaging examinations and the weekend effect ( $p=.121$ ). 25.85% of those who had magnetic resonance imaging examinations were hospitalized.

**Conclusion:** Magnetic resonance imaging examination for neuroimaging purposes has become an emergency department routine. Other magnetic resonance imaging are ordered at a nominal rate. The acquisition of an image took an average of 46 minutes. The weekend effect does not affect the decision of the emergency physician to request a magnetic resonance imaging examination.

**Key words:** emergency department, examination, magnetic resonance imaging, utilization, weekend

## Introduction

Radiological imaging methods are one of the vital parts of diagnostic evaluation, along with physical examination, anamnesis, and laboratory studies. With technological developments in the past thirty years, computed tomography (CT) and magnetic resonance imaging (MRI) have become widespread worldwide and have gained crucial importance in the evaluation of patients [1-5]. Currently, there is a rapid trend towards advanced imaging methods in patients' diagnostic processes, especially in areas such as the emergency

department (ED), where patient density is high and patient evaluation time is very limited [1, 6].

MRI, a powerful medical diagnostic tool, is frequently used as a part of neuroimaging in the ED and has also become a preferred modality in musculoskeletal system pathologies, cardiac rheumatological diseases, and pregnant and pediatric patients [7]. While the use of MRI in ED is gradually increasing [2,7,8], studies on this area's problems are limited. There is a need for an update on how the utilization of MRI examinations in EDs has evolved.

With the first demonstration that weekend hospitalizations increase mortality in Canadian hospitals, the weekend effect has become a research subject [9]. The “weekend effect” refers to more negative outcomes for those who are hospitalized over the weekend than for those who are hospitalized on weekdays. It has been demonstrated that weekend effects have adverse effects, especially in emergency patient groups such as acute stroke, myocardial infarcts, pulmonary embolism, and the need for emergency surgery [10-13]. Patients in need of emergency care constitute the significant burden of ED admissions on the weekend [14]. Additionally, reasons such as the low number of supporting health personnel and clinicians working actively on the weekend, limited access to resources, and difficulty accessing interventional radiologists or specialists for diagnostic endoscopy can cause the weekend effect to have bad results [14-16]. There has been no study evaluating the influence of the weekend effect on MRI orders to determine whether these reasons affect the emergency physician's utilization of imaging methods to reach the correct diagnosis. This study aimed to determine both the MRI utilization trend in the ED and whether the weekend effect affects MRI orders.

Materials and methods  
Study setting and design

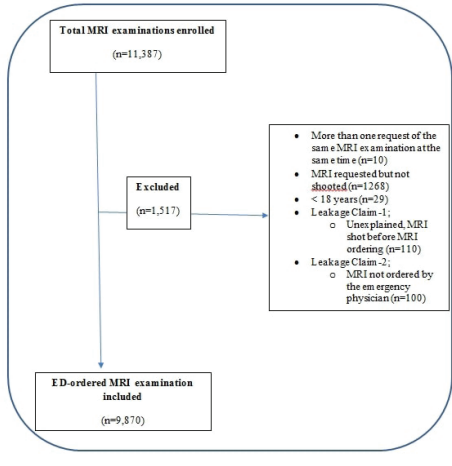
Within the scope of this study, MRI examinations ordered by the emergency physician for patients admitted to the academic emergency department of a tertiary care hospital in Turkey between 01.01.2015 and 31.12.2019 were retrospectively examined for five years. The research was initiated after obtaining approval from the XXXXX University Non-Invasive Health Research Ethics Committee (approval ID 2020/33; dated March 2, 2020).

The study's center is the adult ED of a tertiary care university hospital with 310 beds and a 24-hour MRI service. It is also an ED where traumatic pediatric patients can be admitted. On average, 75,000 emergency patient admissions occur annually. In the center where the study was conducted, the ED requests always have high priority for MRI.

Selection of participants and measurements

Patients aged 18 years and over who were admitted to the ED in 5 years (2015-2019), requested MRI, and underwent imaging were included. Those whose data could not be accessed through the electronic database and archive records of the hospital or who had incomplete data were excluded. Exclusion criteria were given in the form of a flow chart (Figure 1).

Figure 1.



ED= emergency department; MRI=magnetic resonance imaging

In this context, a total of 9870 MRI examinations ordered by the emergency physician in the ED were included in the study. In addition to the total number of MRI examinations, the total number of ED admissions was also recorded.

Ordered MRI examinations were classified into four groups as follows:

- (1) Abdomen + MRI cholangiography + perianal MRI: Abdominopelvic MRI;
- (2) Brain + Neck + Diffusion + Perfusion + MRI, Angiography + MRI, Venography + Vertebra MRI: Neuroimaging;
- (3) Joint + extremity + arthrography MRI: Musculoskeletal MRI;
- (4) Ear, orbital, pituitary gland, temporomandibular joint and breast MRI: Other MRI

The patients included in the study were analyzed in terms of the following: age, gender, application year, application day, working and out of hours (08:00-16:00, 16:00-24:00, 24:00-08:00), type of MRI examination, MRI order-shooting time difference (in hours), weekend effect, and hospitalization.

Statistical analysis

The research data were uploaded and evaluated using IBM SPSS Statistics 19.0 software (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.). Descriptive statistics of categorical variables are presented as numbers and percentages. Descriptive statistics of numerical variables are presented as the mean (±) standard deviation for normally distributed variables and the median (25th-75th percentile) for nonnormally distributed variables. In the comparison of categorical variables, using cross tables, the "Pearson chi-square test" was applied. RStudio for Windows version 1.0.143 (R Studio, Inc., Boston, MA 02210, USA) was used to visualize data. The statistical significance level was accepted as  $p < .05$ .

Results

In the five years (2015-2019), a total of 372,900 patients were 18 years old and older and applied to the ED. During this period, a total of 9870 MRI examinations were performed on 9438 patients (an average of 1.04 MRI requests per patient). In this process, the rate of requesting MRI per application for ED is 2.65% (total number of MRI/total number of applications x 100), while the rate of patients who have undergone MRI is 2.53% (9438/total number of patient applications x 100). In the same period, 29 of the pediatric patients requested MRI in our ED. The low number may be due to the admission of only pediatric patients with traumatic injuries to the adult ED.

The number of MRI examinations per year increased from 1872 MRIs in 2015 to 2219 MRIs in 2019 (i.e., an increase of 19%). The year with the highest number of MRI shots was also determined to be 2018, the year with the highest number of patient applications (Table 1).

Table 1 The total MRI examinations ordered from the emergency department and the total number of admissions to the emergency department by the years

Years	2015	2016	2017	2018	2019
Total number of enrolled patients	63364	70076	73876	88049	77535
Total number of MRI exams	1872	1638	1686	2455	2219
MRI examination/ admission rate (%)	2.95	2.33	2.28	2,78	2,86

MRI=Magnetic resonance imaging

Table 2

Distribution of emergency department-ordered MRI tests by examination types

	MRI examination subtypes	Frequency	Percent
Abdominopelvic	MRI, abdomen, lower	11	0,11
	MRI, abdomen, upper	5	0,05
	MRI, perianal	1	0,01
	MR, cholangiography	10	0,10
Neuroimaging	MRI, angiography	30	0,30
	MRI, venography	19	0,19
	MRI, brain	176	1,78
	MRI, diffusion-weighted	9264	93,86
	MRI, perfusion	12	0,12
	MRI, vertebra, lumbar	143	1,45
	MRI, vertebra, cervical	78	0,79
	MRI, vertebra, thoracic	33	0,33
Musculoskeletal	MRI, arthrography	1	0,01
	MRI, joint, single	53	0,54
	MRI, limb, unilateral	24	0,24
Other	MRI, pituitary gland	3	0,03
	MRI, ear	2	0,02
	MRI, breast	2	0,02
	MRI, Orbita	2	0,02
	MRI, Temporomandibular joint (unilateral)	1	0,01
	Total	9870	100,0

MRI=Magnetic resonance imaging

According to the body region, the distribution of 9870 MRI requests, which the emergency physician ordered during the five years, is presented in Table 2. The most ordered MRI type is neuroimaging (98.8%). Diffusion-weighted (DWI) MRI has been the most specific imaging request from the ED, with a rate of approximately 94%.

The distribution of MRI examinations ordered by the emergency department by year is shown in Figure 2.

Figure 2.

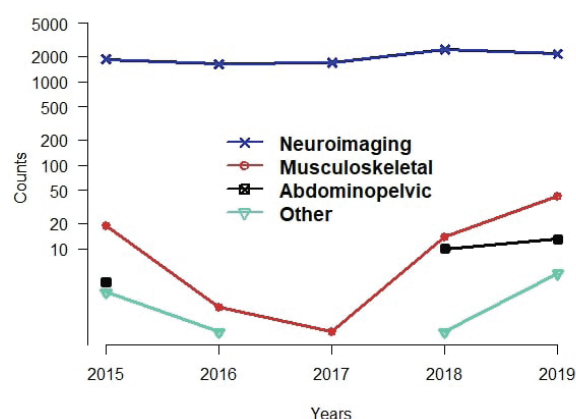


Table 3

Evaluation of ED-ordered MRI examinations in terms of age, gender, working and out of hours, the weekend effect, order and shooting time difference, and hospitalization

Variables		Abdominopelvic	Neuroimaging	Musculoskeletal	Other	Total
Age, years		54±18.9 (21-90)	63.14±18.6 (18-105)	38.01±14.03 (18-83)	40.9±21.9 (18-87)	62.9±18.8 (18-105)
Gender	Female	16 (0.3)	5056 (99)	28 (0.5)	6 (0.1)	5106 (51.7)
	Male	11 (0.2)	4699 (98.6)	50 (1)	4 (0.1)	4764 (48.3)
Working and out of hours	08:00-16:00	18 (0.4)	4200 (98.7)	34 (0.8)	5 (0.1)	4257 (43.1)
	16:00-24:00	7 (0.2)	4115 (98.8)	37 (0.9)	5 (0.1)	4164 (42.2)
	24:00-08:00	2 (0.1)	1440 (99.4)	7 (0.5)	0	1449 (14.7)
The Weekend effect	Weekdays	19 (0.3)	6909 (98.9)	50 (0.7)	10 (0.1)	6988 (70.8)
	Weekend	8 (0.1)	2846 (98.8)	28 (1)	0	2882 (29.2)
Order and shooting time difference, hours		1.89±3.7 (0.10-19.10)	0.76±1.8 (0.10-34.5)	1.85±5.3 (0.10-34.10)	6.58±13.3 (0.10-36.6)	0.78±1 (0.10-36.60)
Hospitalization	Internal wards	1 (0)	2207 (99.8)	3 (0.1)	1 (0)	2212 (86.7)
	Surgical wards	8 (3)	255 (94.1)	5 (1.8)	3 (1.1)	271 (10.6)
	Intensive care unit	0 (0)	69 (100)	0 (0)	0 (0)	69 (2.7)

ED= emergency department; MRI= magnetic resonance imaging; The results are expressed as mean±standard deviation (SD) (min-max), or number and percent (%).

It was observed that more than 97% of the MRI examinations in all years were neuroimaging. In total, neuroimaging was 98.8%, while abdominopelvic MR, musculoskeletal MR, and other MR requests remained below 1%.

MRI examinations ordered from the ED were analyzed in terms of the following variables: age, gender, working and out of hours, weekend effect, MRI order-shot time difference, and hospitalization (Table 3). While the age at which MRI requests for neuroimaging purposes were made stood out as the highest average age, with an average age of 63.14±18.6 years, musculoskeletal MRI requests constituted the youngest group, with 38.01±14.03 years.

A significant difference was found in gender in MRI examinations ordered from the emergency service ( $p=0.033$ ). It

was observed that MRI examinations were ordered more often for females.

According to working and out of hours, over 85% of MRI requests were between 08:00-24:00 hours. Simultaneously, organ-specific (such as breast, pituitary gland, ear MRI) "other MRI" requests were not performed in the ED after 24:00 and on the weekend.

The time between MRI ordering and shooting was, on average, 0.78 (46 min) hours (min 0.1-36.6 hours max). This interval is from least to most; the times were 0.76 hours (46 min) in neuroimaging, 1.85 hours (111 min) in musculoskeletal MRI, 1.89 hours (113 min) in abdominopelvic MRI, and 6.58 hours (395 min) in "other" MRI requests.

When all MRI examinations ordered from the ED were



examined according to the days of the week, it was observed that the rates remained stable between 13-15%. While the day with the least MRI requests was Wednesday, with 13%, the day with the highest number of calls was Monday, with 15.2%. There was no significant difference between the MRI requests made from the ED and the weekend effect ( $p = .121$ ).

Among the patients who had MRI imaging in the ED, 2552 (25.85%) were hospitalized. A total of 86.7% of these patients were admitted to internal services. A total of 2.7% of hospitalized patients were admitted to intensive care. Interestingly, it was observed that none of the patients who received an MRI request other than neuroimaging were admitted to the intensive care unit.

## Discussion

The use of CT in the emergency department is almost indisputable. Nevertheless, information on the place of MRI utilization in the ED is limited [2,7,8]. A study conducted by Rankey et al. on the use of MRI in a tertiary academic center between 2001 and 2005 found the rate of requesting MRI from the ED to be 0.45% [7]. In the study by Quaday et al. investigating the MRI examinations requested from an academic ED between 2007 and 2011, they found that MRI was ordered at a rate of 2.36%, and there was also a decrease in CT requests [2]. We evaluated the MRI examinations ordered in the ED of a tertiary care academic university hospital between 2015 and 2019 and found the MRI order rate to be 2.65%. Considering the studies reported on the utilization of MRI from different parts of the world, it becomes evident that the usage of MRI in emergency services has increased over the years. MRI test requests may have increased due to the widespread use of MRI, as the test is more accessible, does not contain radiation, and provides diagnostic accuracy, as mentioned below. Simultaneously, the low number of physicians in the face of the high number of patients in Turkey and the competition against time in the ED may have increased the imaging requests.

Acute stroke is a medical emergency, and proper prompt treatment of patients and limitation of brain damage are essential to ensure the best possible outcomes [17]. DWI is a necessary imaging method for diagnosing stroke, with a sensitivity exceeding 90% to detect acute ischemia [18]. In addition to the diagnosis of stroke, MRI is more sensitive and specific than CT in the following four items to evaluate spinal trauma: spinal cord injury, extra-axial lesions, ligament injury, and spinal fractures [19]. However, longer exposure time is a disadvantage. In the study of Rankey et al., neuroradiological examinations took first place, with a rate of approximately 87% in MRI examinations requested from the ED [7]. Quaday et al. reported that approximately 94% of the MRI tests ordered from the ED consisted of neuroimaging MR requests [2]. In our study, the number of MRI examinations increased by 19% in the fifth year compared to 2015. At the same time, the number of ED admissions showed an increasing trend. We found that among all MRI requests ordered from the ED, MRI requests for neuroimaging purposes (head and spinal imaging) ranked first, with almost 99%. The brain-DWI request came to the fore in ED-ordered MRI tests at a rate of 94%. For emergency physicians, concern with the medical-legal consequences of skipping a diagnosis, such as an acute stroke diagnosed with high accuracy by MRI, can also be a driving force in MRI orientation [20]. However, due to our study's nature, the medical necessity of the tests requested was not questioned.

The MRI tests requested from the ED are mostly composed of neuroimaging. MRI has become an increasingly used and well-

established imaging modality for diagnosing acute neurological disease processes, particularly those considered neurosurgical emergencies [21]. In addition to brain imaging, spinal imaging is also a part of neuroradiological evaluations. Traumatic cord injury is rare, but early detection of conditions that may cause neural compression, such as an epidural hematoma, compressed disc, or bony material in the spinal canal, is essential to maximize potential neurological recovery in decompressive surgery [22]. Therefore, health services should provide uninterrupted service regardless of the day and time of stroke [23]. For this reason, there should not be any time restrictions for ED-ordered MRI examinations.

It was reported that higher mortality was detected in patients hospitalized for various medical conditions on weekends, which was called the "weekend effect" [9,10,12-14,24,25]. While the influence of the weekend effect on diseases has been studied, to our knowledge, there has been no study investigating the impact of the weekend effect on MRI examinations ordered from the ED. One study reported little delay in neuroimaging (CT/MRI) requests on weekends compared to weekdays in patients with acute stroke [26].

In our study, no significant difference was found between the ED-ordered MRI tests and the weekend effect ( $p = .121$ ). The weekend effect does not affect the MRI request of the emergency physician. In our study, it was observed that MRI was requested in the 13-15% band on all days of the week. The day with the most requests came to the fore as Monday. This may be because Saturdays and Sundays are counted as weekend breaks in Turkey and accumulate on Monday, the first day of work. Emergency physicians order MRI examinations to reach a diagnosis regardless of the notion of working hours.

In addition, it was revealed that "other MRI" test requests, such as breast and pituitary gland, ear MRI were not performed after 24:00 and on weekends in the ED. This may be because imaging tests with low urgency can be requested in polyclinics or because the branches that require expertise do not work out-of-hours.

Acute ischemic stroke occurs in women more than in men [27]. In our study, a significant difference was found between MRI examinations ordered from the ED and gender ( $p=.033$ ). It was observed that more MRI requests were required in female patients in all examination types, except for musculoskeletal MRI requests. In addition to the higher number of female patients for whom MRI was requested, considering the neuroimaging request at the rate of 99% in our study, it is revealed that women mostly presented with neurological complaints.

Additionally, while the time between MRI requests and shootings was performed in a reasonable period of 46 minutes in neuroimaging, it reached almost 7 hours for "other" MRI requests. MRI, a useful imaging method for obtaining a diagnosis in some life-threatening situations, can unfortunately cause a crowd in the ED in terms of the examination duration. Kocher et al. stated that advanced imaging methods such as CT/MRI prolonged the stay in the ED by at least 50 minutes and reported that blood tests and imaging methods are the two most effective ED crowd causes [28]. Redd et al. also noted that the use of MRI in the ED increased significantly after the installation of a fully accessible MRI in the ED and noted that the duration of stay in the ED was prolonged in patients who underwent MRI in the ED. Nevertheless, they reported reduced hospitalization rates or lengths of stay in hospitals in patients presenting to the ED with a suspected stroke [29]. Perhaps because of not abusing MRI in the ED and preventing requests for "other" MRI examinations without urgency from the ED, awareness training can be

provided to clinicians. Informative training can be organized to not engage the clinician with the request for MRI from the ED despite the absence of active complaints.

In the utilization of emergency MRI, we can argue that MRI examinations for neuroimaging have firmly stabilized by almost 99% and have practically become an ED routine in neurological suspicions. Apart from this, it was observed that abdominopelvic MRI, musculoskeletal MRI, and "other" MRI examinations were ordered from the ED at a rate of less than 1%. Since MRI is relatively expensive and requires time, its use in unstable patients remains in the background. However, it may be preferred in special groups such as pregnant or pediatric patients because it does not contain radiation [30]. Although acute abdominal pain is one of the frequent complaints, it was seen that the request for abdominopelvic MRI from the ED remained at approximately 0.3%. Inflammatory bowel diseases such as acute pancreatitis, acute cholecystitis with cholelithiasis, acute appendicitis, Crohn's, and ulcerative colitis cause abdominal pain requiring hospitalization or surgery in some cases [31]. Familiarity with MRI may increase over time in the ED evaluation of other abdominal pathologies, such as the fact that MRI-cholangiopancreatography has largely replaced the diagnostic endoscopic cholangiopancreatography evaluation of acute abdomen [32]. Nevertheless, the increasing use of abdominopelvic MRI, especially in busy EDs, seems to be a remote possibility for now.

One of the common reasons for emergency services is undoubtedly complaints about the musculoskeletal system. Although not always used as a primary imaging modality in the emergency setting, MRI can be a valuable aid in diagnosing and treating musculoskeletal emergencies. The benefit of MRI in detecting small infection foci, necrosis, and pathological fluid accumulations is superior to other imaging techniques such as CT and ultrasonography. A few musculoskeletal emergencies that are thought to be useful in diagnosis and treatment management can be listed as rhabdomyolysis, diabetic myonecrosis, septic arthritis, cellulitis, necrotizing fasciitis, compartment syndrome, and ligament and tendon injuries [33]. However, the usefulness of these in the ED does not seem possible due to the time requirement and high cost. In our study, it was observed that musculoskeletal MRI requests from the ED were realized at a rate of 0.8%, and at the end of five years, a total of 10 "other" MRI tests were requested. Emergency physicians do not adopt "other" MRI examinations, such as breast, pituitary gland, and ear examinations, from the ED.

Finally, we witnessed that 1 out of every four patients for whom MRI was requested from the ED were hospitalized as a result. A total of 86.7% of these patients were admitted to internal services. A total of 2.7% of hospitalized patients went to the intensive care unit. Interestingly, it was observed that no

patients were admitted to the intensive care unit except those who underwent MRI for neuroimaging purposes. It has been reported that there is a strong relationship between in-hospital mortality and acutely ill patients hospitalized after MRI performed in the ED. Additionally, it has been stated that the delay in the time of MRI acquisition is related to the duration of hospitalization [34]. Although we did not reach the mortality outcomes of the patients, we believe that the high rate of hospitalization of the patients who underwent MRI and its association with in-hospital mortality as stated in the previous study and the patients who had MRI examinations requested from the ED are a riskier group than those who did not have MRI examinations ordered. We believe that the clinician should keep these factors in mind.

## Limitations

The study aimed to reveal which MRI examinations have been requested from an academic ED in the last five years and the utilization of MRI in the ED. It was also investigated whether the weekend effect affected the emergency physician's decision to request an MRI test. Thus, although the following issues were excluded from the study's subject, they were accepted as limitations. The study's first limitation was that it was retrospective. Second, the reasons for the MRI request were not questioned. Third, the effect of MRI on the diagnosis was not examined. Fourth, it was not checked whether additional or other imaging methods were performed before or after MRI. Fifth, medical necessity was not questioned in the MRI requests. Sixth, the effect of a patient's presence on the need for sedation for MRI or awaiting stabilization due to unstable conditions on the duration of exposure could not be examined. Seventh, a cost analysis was not performed. These issues also need to be investigated.

## Conclusion

There has been an increase in MRI requests in the ED. Although almost all MRI examinations are requested from the ED, MRI requests for neuroimaging purposes have become an emergency department routine. It was observed that MRI requests added an average of 46 minutes to the length of ED stay. The weekend effect has no impact on the decision of the emergency physician to request an MRI examination.

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## References

1. Dick EA, Varma D, Kashef E, Curtis J. Use of advanced imaging techniques during visits to emergency departments—implications, costs, patient benefits/risks. *Br J Radiol.* 2016; 89(1061):20150819. doi: 10.1259/bjr.20150819.
2. Quaday KA, Salzman JG, Gordon BD. Magnetic resonance imaging and computed tomography utilization trends in an academic ED. *Am J Emerg Med.* 2014; 32(6):524-528. doi: 10.1016/j.ajem.2014.01.054.
3. Tung M, Sharma R, Hinson JS, Nothelle S, Pannikottu J, Segal JB. Factors associated with imaging overuse in the emergency department: a systematic review. *Am J Emerg Med.* 2018; 36(2):301-309. doi: 10.1016/j.ajem.2017.10.049.
4. Oguz KK, Yousem DM, Deluca T, Herskovits EH, Beauchamp NJ. Effect of emergency department CT on neuroimaging case volume and positive scan rates. *Acad Radiol.* 2002; 9(9):1018-1024. doi: 10.1016/s1076-6332(03)80477-4.

5. Demir MC, Akkas M. Awareness of Risks Associated with the Use of Plain X-Ray, Computed Tomography, and Magnetic Resonance Imaging Among Emergency Physicians and Comparison with that of Other Physicians: A Survey from Turkey. *Med Sci Monit.* 2019; 25:6587-6597. doi: 10.12659/MSM.918381.
6. Korley FK, Pham JC, Kirsch TD. Use of advanced radiology during visits to US emergency departments for injury-related conditions, 1998-2007. *JAMA.* 2010; 304(13):1465-1471. doi: 10.1001/jama.2010.1408.
7. Rankey D, Leach JL, Leach SD. Emergency MRI utilization trends at a tertiary care academic medical center: baseline data. *Acad Radiol.* 2008; 15(4):438-443. doi: 10.1016/j.acra.2008.01.003.
8. Ohana O, Soffer S, Zimlichman E, Klang E. Overuse of CT and MRI in paediatric emergency departments. *Br J Radiol.* 2018; 91(1085):20170434. doi: 10.1259/bjr.20170434.
9. Bell CM, Redelmeier DA. Mortality among patients admitted to hospitals on weekends as compared with weekdays. *N Engl J Med.* 2001; 345(9):663-668. doi: 10.1056/NEJMsa003376.
10. Roberts SE, Thorne K, Akbari A, Samuel DG, Williams JG. Mortality following Stroke, the Weekend Effect and Related Factors: Record Linkage Study. *PLoS One.* 2015; 10(6):e0131836. doi: 10.1371/journal.pone.0131836.
11. Kumar G, Deshmukh A, Sakhuja A, Taneja A, Kumar N, Jacobs E et al. Acute myocardial infarction: a national analysis of the weekend effect over time. *J Am Coll Cardiol.* 2015; 65(2):217-218. doi: 10.1016/j.jacc.2014.09.083.
12. Coleman CI, Brunault RD, Saulsberry WJ. Association between weekend admission and in-hospital mortality for pulmonary embolism: An observational study and meta-analysis. *Int J Cardiol.* 2015; 194:72-74. doi: 10.1016/j.ijcard.2015.05.098.
13. Zapf MA, Kothari AN, Markossian T, Gupta GN, Blackwell RH, Wai PY et al. The "weekend effect" in urgent general operative procedures. *Surgery.* 2015; 158(2):508-514. doi: 10.1016/j.surg.2015.02.024.
14. Somasundram K, Neville JJ, Sinha Y, Agarwal T, Raje D, Sinha A et al. The weekend effect - How can it be mitigated? Introduction of a consultant-delivered emergency general surgical service. *Ann Med Surg (Lond).* 2020; 57:315-320. doi: 10.1016/j.amsu.2020.08.013.
15. Scott JW, Tsai TC, Neiman PU, Jurkovich GJ, Utter GH, Haider AH et al. Lower emergency general surgery (EGS) mortality among hospitals with higher-quality trauma care. *J Trauma Acute Care Surg.* 2018; 84(3):433-440. doi: 10.1097/TA.0000000000001768.
16. Ozdemir BA, Sinha S, Karthikesalingam A, Poloniecki JD, Pearse RM, Grocott MP et al. Mortality of emergency general surgical patients and associations with hospital structures and processes. *Br J Anaesth.* 2016; 116(1):54-62. doi: 10.1093/bja/aev372.
17. Gomez CR. Time is brain: the stroke theory of relativity. *J Stroke Cerebrovasc Dis.* 2018; 27(8):2214-2227. doi: 10.1016/j.jstrokecerebrovasdis.2018.04.001.
18. Gonzalez RG, Schaefer PW, Buonanno FS, Schwamm LH, Budzik RF, Rordorf G et al. Diffusion-weighted MR imaging: diagnostic accuracy in patients imaged within 6 hours of stroke symptom onset. *Radiology.* 1999; 210(1):155-162. doi: 10.1148/radiology.210.1.r99ja02155.
19. Provenzale J. MR imaging of spinal trauma. *Emerg Radiol.* 2007; 13(6):289-297. doi: 10.1007/s10140-006-0568-7.
20. Birbeck GL, Gifford DR, Song J, Belin TR, Mittman BS, Vickrey BG. Do malpractice concerns, payment mechanisms, and attitudes influence test-ordering decisions? *Neurology.* 2004; 62(1):119-121. doi: 10.1212/01.wnl.0000101709.87316.0c.
21. Rozell JM, Li S. Recognition and appropriate use of magnetic resonance imaging for emergent neuroradiology. *Semin Ultrasound CT MR.* 2017; 38(4):424-438. doi: 10.1053/j.sult.2017.02.007.
22. Fehlings MG, Vaccaro A, Wilson JR, Singh A, W Cadotte D, Harrop JS et al. Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PloS one.* 2012; 7(2):e32037. doi: 10.1371/journal.pone.0032037.
23. Angerer S, Buttinger K, Stummer H. The weekend effect revisited: evidence from the Upper Austrian stroke registry. *Eur J Health Econ.* 2019; 20(5):729-737. doi: 10.1007/s10198-019-01035-4.
24. Aylin P, Yunus A, Bottle A, Majeed A, Bell D. Weekend mortality for emergency admissions. A large, multicentre study. *Qual Saf Health Care.* 2010; 19(3):213-217. doi: 10.1136/qshc.2008.028639.
25. Pauls LA, Johnson-Paben R, McGready J, Murphy JD, Pronovost PJ, Wu CL. The weekend effect in hospitalized patients: a meta-analysis. *J Hosp Med.* 2017; 12(9):760-766. doi: 10.12788/jhm.2815.
26. Jungehulsing G, Rossnagel K, Nolte CH, Muller-Nordhorn J, Roll S et al. Emergency department delays in acute stroke—analysis of time between ED arrival and imaging. *Eur J Neurol.* 2006; 13(3):225-232. doi: 10.1111/j.1468-1331.2006.01170.x.
27. Persky RW, Turtzo LC, McCullough LD. Stroke in women: disparities and outcomes. *Curr Cardiol Rep.* 2010; 12(1):6-13. doi: 10.1007/s11886-009-0080-2.
28. Kocher KE, Meurer WJ, Desmond JS, Nallamothu BK. Effect of testing and treatment on emergency department length of stay using a national database. *Acad Emerg Med.* 2012; 19(5):525-534. doi: 10.1111/j.1553-2712.2012.01353.x.
29. Redd V, Levin S, Toerper M, Creel A, Peterson S. Effects of fully accessible magnetic resonance imaging in the emergency department. *Acad Emerg Med.* 2015; 22(6):741-749. doi: 10.1111/acem.12686.
30. Ditkofsky NG, Singh A, Avery L, Novelline RA. The role of emergency MRI in the setting of acute abdominal pain. *Emerg Radiol.* 2014; 21(6):615-624. doi: 10.1007/s10140-014-1232-2.
31. Peery AF, Dellon ES, Lund J, Crockett SD, McGowan CE, Bulsiewicz WJ et al. Burden of gastrointestinal disease in the United States: 2012 update. *Gastroenterology.* 2012; 143(5):1179-1187.e3. doi: 10.1053/j.gastro.2012.08.002.
32. Stoker J. Magnetic resonance imaging and the acute abdomen. *Br J Surg.* 2008; 95(10):1193-1194. doi: 10.1002/bjs.6378.
33. Mehta P, Morrow M, Russell J, Madhuripan N, Habeeb M. Magnetic resonance imaging of musculoskeletal emergencies. *Semin Ultrasound CT MR.* 2017; 38(4):439-452. doi: 10.1053/j.sult.2017.04.001.
34. Cournane S, Creagh D, O'Hare N, Sheehy N, Silke B. MRI in acutely ill medical patients in an Irish hospital: influence on outcomes and length of hospital stay. *J Am Coll Radiol.* 2014; 11(7):698-702. doi: 10.1016/j.jacr.2014.01.014.