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An economic impact of incorrect referrals for MRI and CT scans: A retrospective analysis

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Abstract

Background and Aims: Up to date, no research on the economic efficacy of diagnostic modalities, such as magnetic resonance imaging (MRI) and computerized tomography (CT), has been done in Central Asia. The aim of this study was to analyse the inappropriate appointments of MRI and CT scanning procedures in Kazakhstan.

Methods: We used the imaging diagnostic reports and medical records from 9725 planned outpatient CT and MRI exams performed in two major hospitals in Almaty. The study period was for the period 2014–2019. The independent experts-radiologists evaluated the MRI and CT exams for validity using the ACR® compliance standards and RCR recommendations.

Results: The results showed that the combined costs of MRI and CT scans increased by $17.982 between 2014 ($22.537) and 2019 ($40.519), $p = 0.002$. The highest rate of MRI examinations was observed in 2019, with a rate of 6.9 per 10,000 people. It was determined that in 2019 the highest rate for men who undertook CT was equal to 12.4 per 10,000 people, while for women it was equivalent to 5.7 per 10,000 patients. The majority of non-corresponding imaging examinations ($n = 1304$) were referred for MRI and CT scans by general practitioners. We detected the irrational referrals for head and neck radiological examinations in $n = 178$ (13.7%) cases, and the abdominal cavity checks in $n = 249$ (19.1%) cases ($p = 0.001$). The main portion of erroneously unreasonable referrals for examination of the abdominal organs was made by surgeons in $n = 43$ (3.3%) cases.

Conclusion: The findings indicated an increase in the number of referrals for unnecessary CT and MRI tests over the research period (2014–2019). It had a substantial impact on the rise in healthcare system expenses. The results demonstrate the need for the education of GPs and improving the approaches for diagnostics.

KEYWORDS

diagnostic imaging, health expenditures, magnetic resonance imaging, medical overuse, tomography

1 | INTRODUCTION

Access to top-notch medical technology is crucial for healthcare institutions all over the world.[1] It focuses on using cutting-edge tools, modalities, and techniques to diagnose and treat a range of illnesses. The cost of creating and implementing medical technology, particularly in underdeveloped nations, is rising steadily on a worldwide scale.[2] In most developed countries, health systems deal with problems connected to health management despite a lack of funds.[3] It is anticipated that healthcare prices will rise even further. It includes the cost of diagnostics and radiographic techniques like magnetic resonance imaging (MRI), computerized tomography (CT), and ultrasound.[4]

Given that diagnostic procedures are expensive, it is crucial to closely control and monitor associated expenses.[5] Diagnostic imaging in all of its forms is responsible for a sizable portion of these costs.[6]

Unfortunately, doctors frequently order imaging tests (such as CT and MRI) without strong justifications.[7] It's unknown why imaging techniques are used so frequently. It could be attributed to physicians' intention to enhance diagnostics and identify life-threatening illnesses at an early stage.[7]

Apart from the financial burden, there is a danger from the unnecessary exposing the patients to gamma radiation (CT and X-rays)[8,9] as a result of self-referrals or doctors' prescriptions. Self-referral can lead to a conflict of interest due to the physicians' interest in the profit.[10] Besides, some radiographers can partially benefit from high patient traffic too.[11]

A lot of attention has been paid to appropriate usage of visual diagnostic tools in healthcare organizations. It encompasses lowering pointless and unwarranted recommendations and referrals for diagnostic radiological tests.[12] The Medicare system is one such example. However, the majority of these initiatives were based on the lack of clinical recommendations. Moreover, there no strategies proposed to optimize diagnostics recommendations that taking into account of the unnecessary harm to the patient.[13]

Up to date, studies aimed at the correct assessment of referrals for MRI and CT scanning procedures have not yet been carried out in Kazakhstan yet. This study aimed to analyse inappropriate appointments for MRIs and CTs in Kazakhstan between 2014 and 2019.

2 | METHODS

2.1 | Ethical issues

The study was approved by the Kazakhstan School of Public Health's Local Ethics Committee in Almaty, Kazakhstan (protocol of the Local Ethics Committee No IRB -A191 issued from 23.05. 2022).

2.2 | Study design

A retrospective study was conducted in the city of Almaty, Kazakhstan. X-ray reports and medical records (CT and MRI studies) of the adult population were obtained from 9725 patients treated at City Clinical Hospital No. 7 and National Scientific Centre for Surgery from 01/02/2014 to 10/12/19. Referrals from outpatient clinics in Almaty for computed and magnetic resonance imaging were examined as a part of the government-support healthcare and chargeable services as well. The data set was held according to the CONSORT criteria.[14]

2.3 | Study variables

In our analysis, we removed about 4% of records due to missing information. There were no obvious patterns in these crossed-out records compared to full data records. Categories of independent variables were as follows: gender, age, education, payment method, field of study, and MRI/CT Referral Form.

2.4 | Setting

Almaty's City Clinical Hospital No. 7 is a medical facility with 1000 beds. It serves as an in-patient, out-patient, consultative, and diagnostic healthcare organization on the national level. National Scientific Centre of Surgery is one of the top multifunctional medical institutions in Kazakhstan.

2.5 | Data and patients

The "National Scientific Centre for Health Development named after Salidat Kairbekova" provided information on the total number of radiological studies completed in the period 2017–2021. There were six types of CT/MRI scans of main organs, including the brain, chest organs, abdomen, retroperitoneal organs, pelvic organs, osteoarticular system, and others.

Data on Almaty's overall population was compiled using demographic statistics obtained from the Statistics Committee of the Ministry of National Economy of Kazakhstan.[14]

The images were sub-classified according to the scanned organs: head–neck, bones–joints, abdominal cavity, tiny pelvis, spine, chest, and blood vessels. The specialization of the referring doctor was used to categorize imaging requests: general practitioners, surgeons, pediatricians, and other specialists.

2.6 | Evaluation criteria

The professional radiologists evaluated the appropriateness and validity of the performed MRI and CT exams using the ACR® compliance standards and RCR recommendations. The ACR Eligibility Criteria (ACR AC) are evidence-based recommendations to help patients, referring doctors, and other healthcare professionals choose the best imaging or therapy option for a certain clinical condition.[15]

To make the best imaging decision, the ACR set was created, and then, constantly updated (ACR Eligibility Criteria).

The radiologists got access to digitized patient medical records that contained detailed medical histories, results of laboratory tests, and images from earlier diagnostic imaging procedures.

The studies were categorized into three groups: suitable, improper, and uncertain based on the type of choice made utilizing radiological data and medical records. The academic radiologist conducted this study to reduce the initial compliance analysis's margin of error.

2.7 | Statistical analysis

Software called SPSS was used to do the statistical analysis (version 25.0, IBM SPSS Inc.). Statistics were deemed significant at $p < 0.05$. Mean (SD) and *n* (%) were used to depict continuous and categorical variables, respectively. The χ^2 test and Fisher's exact test were used to calculate categorical variables. All results are presented as weighted values. We have also used information on the demographic characteristics obtained from the Committee on Statistics of the Ministry of National Economy of Kazakhstan. $p < 0.05$ was considered statistically significant.

3 | RESULTS

The data for Almaty city are displayed at Table 1 (period 2014–2019). This information was obtained from the official population census and open data sources. Almaty city had a population of 1,574,172 people in 2014. That number increased up to 1,672,105 people in 2015 (+6.22%). The following years Almaty's population grew by 3.29% in 2016, 2.87% in 2017, and 3.14% in 2019.

Indications for MRI and CT exams and the associated costs are shown in Table 2 (2014–2019). The number of MRI screens were *n* = 657 and CT exams *n* = 750 (in 2014). The total costs were 22,864 USD. MRI and CT scan accounted for 22,864 USD in 2015 and 23,467 USD in 2016.

MRI and CT scans costed 29,441 USD in 2017, and 22,838 USD in 2018. Compared to MRI examinations (*n* = 852), the number of CT scans performed in 2019 (*n* = 1654) was nearly two times higher. In addition, the total cost of MRI and CT scans increased by 17,982 USD from 2014 (22,537 USD) to 2019 (40,519 USD), which was statistically significantly different ($p = 0.002$). According to the number of MRI and CT examination cases, there were 460 men and 197 women who underwent MRI tests in 2014. Analysis showed that more males (*n* = 488) underwent CT scans than women (*n* = 262). A total of 1623 MRI and CT scans were carried out in 2017. It encompasses *n* = 535 men and *n* = 229 women who underwent MRI scans, and *n* = 558 men and *n* = 301 women underwent CT scans. The most of MRI and CT tests (*n* = 2506), were performed in 2019 compared to prior years. In addition, in 2019, almost two times more men were referred for CT than women (*n* = 1075 cases vs. *n* = 597 cases).

TABLE 1 Population of Almaty in the years 2014 through 2019.

Year	Sex		Total	Change
	M	F		
2019	863,474	1,022,265	1,885,739	+57,415 (+3.14%)
2018	834,930	993,394	1,828,324	+51,674 (+2.91%)
2017	811,504	965,146	1,776,650	+49,613 (+2.87%)
2016	789,622	937,415	1,727,037	+54,932 (+3.29%)
2015	764,620	907,485	1,672,105	+97,933 (+6.22%)
2014	718,549	855,623	1,574,172	+66,663 (+4.42%)

TABLE 2 A number of MRI and CT exams conducted and their relative costs for the period of 2014–2019.

Year	Index		
	MRI exam	CT exam	Total cost[a] (MRI/CT)
2014	657	750	22,537
2015	654	823	22,864
2016	672	768	23,467
2017	764	859	29,441
2018	638	945	22,838
2019	852	1654	40,519
2014 vs. 2019	195	904	17,982[b]

Abbreviations: ANOVA, analysis of variance; CT, computerized tomography; MRI, magnetic resonance imaging.

[a]Cost was defined as money paid to CT and MRI providers. in dollars at the price of the National Bank of the Republic of Kazakhstan as of 08/09/2022.

[b]The *p*-value for the difference in value between 2014 and 2019 was 0.0024 (one-way ANOVA).

Figure 1 shows the number of MRI (A) and CT (B) scans per 10,000 people in Almaty for the years 2014–2019 (by gender). The highest rates of MRI and CT exams were recorded in 2014, totaling 8.9 per 10,000 of the population. The lowest rates were observed in 2016 (8.3 per 10,000). The greatest rates of MRI and CT exams were found to be 9.1 in 2017 and 13.3 in 2019 per 10,000 of the population of Almaty. These years demonstrated the highest number of MRI and CT examinations performed.

According to the analysis of MRI studies, there were 6.4 MRIs performed on men per 10,000 people in 2014. It was about three times greater than the 2.3 MRIs performed on women per 10,000 people. Almaty's male population underwent 2.4 MRI exams per 10,000 people in 2017. The lowest level was recorded in 2018 (1.9 MRI examinations per 10,000 population). The year with the highest use of MRI was 2019. The men were more likely to use this method than women: 6.9 per 10,000 compared with 2.5. According to CT studies conducted in 2014, men used CT for diagnostic purposes at a rate of 6.8 per 10,000 of the population, while women underwent CT exams at a rate of 3.1 per 10,000 of the Almaty population. Men and

women used CT scans for diagnostic purposes less frequently in 2017 than they did the year before, at 6.9 and 3.1 per 10,000 people, respectively. Further research in 2018 revealed a rise in the usage of CT scans, which resulted in the highest rates ever recorded in 2019—12.4 per 10,000 for males and 5.7 per 10,000 for women.

Table 3 lists the measures of the reliability and adherence of the performed MRI and CT investigations. Of the total number of MRI and CT scans performed, $n = 8421$ were justified, and $n = 1304$ were deemed inappropriate. Depending on the patient's gender, the results of the MRI and CT examinations typically agreed with the preliminary diagnosis in men in $n = 5853$ (69.5%) instances and did not in women in $n = 687$ (52.7%) cases. This difference was statistically significant ($p = 0.02$).

According to age, a mismatch in the research data was discovered in $n = 328$ cases (25.2%). The conformity was only detected in $n = 530$ (6.3%) cases ($p = 0.001$). In the group "18 to 30 years old," there was a statistically significant difference ($p = 0.001$) between the number of irrelevant studies ($n = 294$, 22.5%) and the number of relevant studies ($n = 642$, 7.6%). Moreover, the number of pertinent MRI and CT studies in the age range of 31–40 years was higher ($n = 2258$, 32.3%) compared to noncorresponding studies ($n = 40$, 3.1%), p-value of 0.001. In the age groups of 41–50 years and 51–60 years, respectively, the frequency of MRI and CT exam appointments that were kept outweighed inconsistent use of these research methods, with statistically significant differences of $p = 0.012$ and $p = 0.037$. However, there were higher instances of inappropriate MRI and CT visits in the age category of 71 years and older, with an indicator of $n = 358$ (27.5%) compared with the equivalent referrals $n = 825$ (9.8%). The frequency of MRI and CT test appointments that were kept exceeded inconsistent use of these research methods in the age categories of 41–50 years and 51–60 years, respectively, with statistically significant differences of $p = 0.012$ and $p = 0.037$, respectively.

There were higher cases of unsuitable MRI and CT visits in the age group of 71 years and older, with an indicator of $n = 358$ (27.5%) compared with the comparable referrals $n = 825$ (9.8%).

Regardless of the subjects' education or the method of payment for their MRIs and CT scans, no statistically significant difference between the groups of participants who were in compliance with using these diagnostic techniques and those who weren't was found out ($p = 0.05$).

Table 4 provides information on the analysis of noncompliance situations involving the usage of MRI and CT scans. The majority of

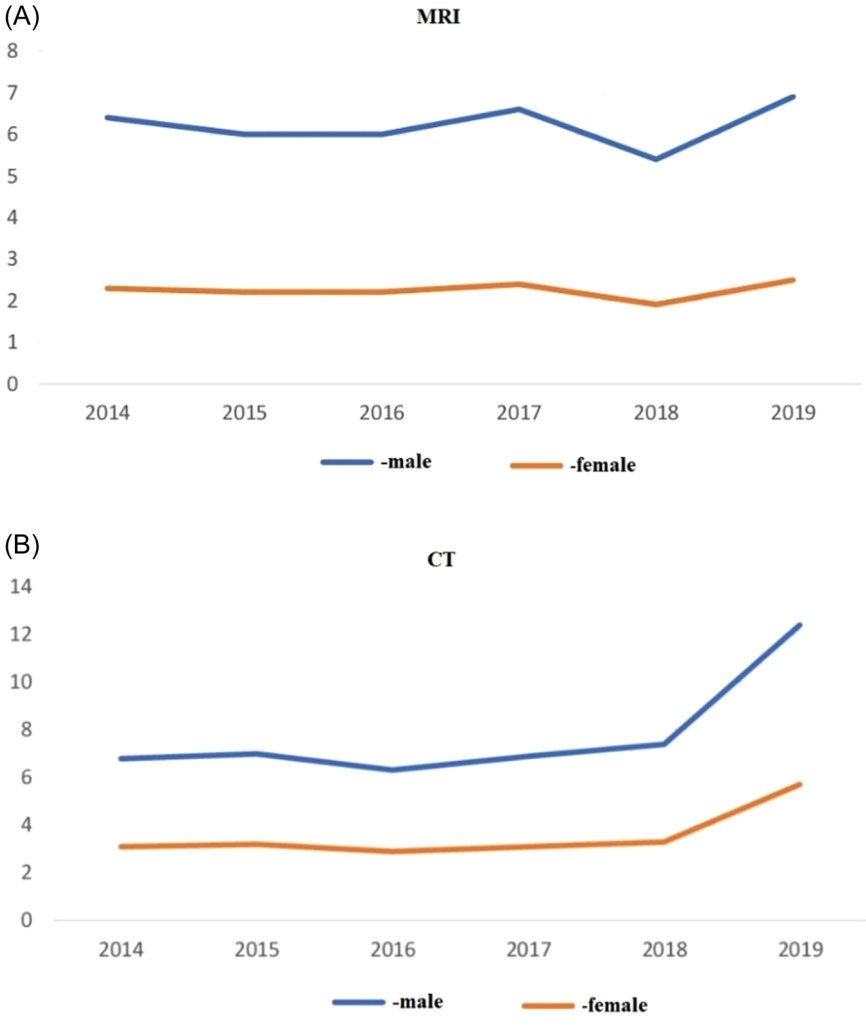

FIGURE 1 Number of MRI (A) and CT (B) scans per 10,000 in Almaty, broken down by gender, for the years 2014–2019. CT, computerized tomography; MRI, magnetic resonance imaging.

the $n = 1304$ noncompliant exams were referred for MRI and CT scans by general practitioners, mainly, their unwarranted referrals for examinations of the head and neck region in $n = 178$ (13.7%) cases and the abdominal cavity in $n = 249$ (19.1%) cases, which were statistically more significant than the errors of the groups of doctors ($p = 0.001$).

TABLE 3 Indicators of the reliability and adequacy of the MRI and CT tests carried out in Almaty during the research period.

Characteristic	Corresponds $n = 8421$ n (%)	Does not match $n = 1304$ n (%)	Unknown $n = 311$ n (%)	p
Sex				
Male	5853 (69.5)	687 (52.7)	195 (62.7)	0.02
Female	2568 (30.5)	617 (47.3)	116 (37.3)	
Age				
Under 18	530 (6.3)	328 (25.2)	12 (3.8)	0.001
18–30	642 (7.6)	294 (22.5)	35 (11.3)	0.001
31–40	2258 (26.8)	40 (3.1)	45 (14.5)	0.001
41–50	2721 (32.3)	163 (12.5)	58 (18.6)	0.012
51–60	1445 (17.2)	121 (9.3)	107 (34.4)	0.037
71 and older	825 (9.8)	358 (27.5)	54 (17.4)	0.024
Education				
Without education	1937 (23.0)	378 (29.0)	53 (17.0)	0.571
Average	4884 (58.0)	743 (57.0)	158 (50.8)	0.722
Higher	1600 (19.0)	183 (14.0)	100 (32.2)	0.566
Payment type				
Country	2358 (28.0)	170 (13.0)	37 (11.9)	0.064
For a fee	6063 (72.0)	1134 (87.0)	274 (88.1)	0.089

Abbreviations: CT, computerized tomography; MRI, magnetic resonance imaging.

Paediatricians sent patients for more unneeded CT and MRI scans than specialists (2.4%) or surgeons (2.4%), with $n = 65$ (4.9%). Nevertheless, paediatricians' error rates were lower than those of general practitioners (13.7%), which was regarded a statistically significant difference ($p = 0.001$).

Between specialists and surgeons, there were no differences in the incorrect referrals on MRI and CT scans. Apart from that, it was shown that surgeons made erroneously unreasonable referrals for investigation of the abdomen organs more frequently in n = 43 (3.3%) cases, and among specialists, referrals for evaluation of the chest organs predominated in $n = 44$ (3.3%) cases of unjustifiable MRI and CT tests.

The results of the analysis of CT and MRI tests performed in all country' territory between 2018 and 2021 are shown in Table 5. 2018 saw more CT scans ($n = 288441$, 78.3%) than MRI tests ($n = 80126$, 21.7% of cases), as opposed to $n = 80126$ (21.7% of cases). Brain CT and MRI scans were the most common imaging procedures at all sites, with $n = 109828$ (38.1%) and $n = 40983$ (51.1%), respectively. According to CT studies, brain CTs were performed in $n = 109828$ (38.1%) instances in 2018 and more brain MRIs than other MRIs overall were performed in $n = 40983$ (51.1%) cases. While in 2018 there were 14931 cases of CT of the pelvic organs and 278 instances of MRI of the chest (0.3%) as the least common procedures.

In 2019, the number of CT tests (81.7%) exceeded MRI exams (18.3%). Brain CT and MRI scans were conducted in $n = 134895$ (41.3%) cases and $n = 41293$ (56.3%) instances (in 2019), respectively.

In 2020, $n = 74,301$ (13.6%) and $n = 470,756$ (86.4%) cases, respectively, got MRI exams. The number of CT exams of the chest increased in 2020 compared with other years ($n = 180,817$ or 38.4%). The highest number of brain MRI exams ($n = 39,285$ or 52.9%) was detected in 2020.

The total amount of CT exams conducted in 2021 was $n = 860,477$ (91.4%). It was much higher than the MRI exams conducted, $n = 81,303$ (8.6%). The number of CT tests of the chest ($n = 47,4421$ or 55.1% of all examinations) and the number of CT examinations of the brain ($n = 202,294$, or 23.5% of all examinations)

TABLE 4 Depending on the credentials of the referring physician in Almaty for the research period, there have been instances of inconsistent usage of MRI and CT examinations.

Does not match MRI and CT, $n = 1304$								
	Research department							
Specialization	Head and neck, n (%)	Bones and joints, n (%)	Abdomen, n (%)	Small pelvis, n (%)	Spine, n (%)	Rib cage, n (%)	Vessels, n (%)	Total
GP	178 (13.7)	26 (1.9)	249 (19.1)	96 (7.4)	58 (4.4)	19 (1.5)	13 (1.0)	2076
Specialists	31 (2.4)	15 (1.1)	20 (1.5)	37 (2.8)	16 (1.2)	44 (3.3)	20(1.5)	593
Surgeons	31 (2.4)	6 (0.5)	43 (3.3)	27 (2.1)	16 (1.2)	19 (1.5)	14 (1.1)	508
Pediatricians	65 (4.9)	62 (4.8)	39 (3.0)	26 (2.0)	46 (3.6)	33 (2.5)	55 (4.2)	1059
Total	305 (23.4)	109 (8.3)	351 (26.9)	186 (14.3)	136 (10.4)	115 (8.8)	102 (7.8)	4237

Abbreviations: CT, computerized tomography; MRI, magnetic resonance imaging.

significantly increased in 2021. Moreover, $n = 37{,}912$ (46.6%) of the MRI scans carried out in 2021 were brain-related MRI studies.

Thus, compared to 2018, the frequency of CT and MRI studies increased by 198.3% and 1.4%, respectively, in 2021. The number of chest CT scans increased by +1007.2% in 2021 compared with 2018. At the same time, the number of brain CT scans grew up by 84.1%. There was a decrease −2.9% in the number of CT exams performed on other body parts in 2021 (compared with 2018).

There was an increase (+17.2%) in the number of chest MRI scans in 2021 compared to 2018. We detected a growth (90.8%) in the number of pelvic organ MRI scans. In contrast to 2018, MRI scans of the abdominal organs and the retroperitoneal space increased by 14.2% in 2021, while scans of other areas grew by 15.4%. It should be mentioned that there were 7.4% less brain and 9.0% fewer musculoskeletal MRI investigations performed in 2021 than there were in 2018.

TABLE 5 Cases of CT and MRI procedures carried out within the Republic of Kazakhstan's territory between 2018 and 2021.

Field of study	2018 (*n*, %)		2019		2020		2021		2018 vs. 2021 (%)	
	CT	MRI	CT	MRI	CT	MRI	CT	MRI	CT	MRI
Total studies	288,441 (78.3)	80,126 (21.7)	326,368 (81.7)	73,286 (18.3)	470,765 (86.4)	74,301 (13.6)	860,477 (91.4)	81,303 (8.6)	198.3	1.4
Brain	109,828 (38.1)	40,983 (51.1)	134,895 (41.3)	41,293 (56.3)	132,387 (28.1)	39,285 (52.9)	202,294 (23.5)	37,912 (46.6)	84.1	−7.4
Chest organs	42,847 (14.8)	278 (0.3)	53,646 (16.4)	422 (0.6)	180,817 (38.4)	2078 (2.8)	474,421 (55.1)	326 (0.4)	1007.2	17.2
Organs of the abdominal cavity and retroperitoneal space	41,146 (14.3)	8156 (10.3)	48,845 (14.9)	8935 (12.2)	55,929 (11.9)	7952 (10.7)	64,389 (7.5)	9320 (11.5)	56.4	14.2
Pelvic organs	14,931 (5.2)	4207 (5.2)	15,821 (4.8)	5118 (7.0)	17,429 (3.7)	6449 (8.7)	18,027 (2.1)	8029 (9.9)	20.7	90.8
Osteo-articular system	29,531 (10.2)	19,961 (24.9)	31,905 (9.8)	12,890 (17.6)	39,370 (8.4)	13 181 (17.7)	52,641 (6.1)	18,162 (22.3)	78.2	−9.0
Other	50,158 (17.4)	6541 (8.2)	41,256 (12.6)	4628 (6.3)	44,833 (9.5)	5356 (7.2)	48,705 (5.7)	7554 (9.3)	−2.9	15.4

Abbreviations: CT, computerized tomography; MRI, magnetic resonance imaging.

4 | DISCUSSION

For many healthcare organizations around the world, the appropriateness of the recommendation for radiographic scanning remains a problem.[16] It should be pointed out that every year the number of MRI and CT studies tends to increase. In turn, it triggers a rise in the number of unnecessary diagnostic procedures.[17] As a result, it leads to the growth of the number of medical personnel involved and associated costs.[18]

Here, we evaluated the effectiveness of imaging in Kazakhstan for the first time. According to our findings, the number of MRI and CT scans increased every year. Costs for visual diagnostic tests grew up in 2019 compared with 2014 as a result.

The findings imply that about a quarter of CT scans performed on the general population was inappropriate and unnecessary.[17] Our findings are consistent with results of previous studies that demonstrated a yearly rise in the utilization of CT and MRI scans.[18]

Another factor that can contribute to the rise of non-eligible screening is the patient's request for the radio-graphic test.[19] In fact, a range of factors can impact the frequency of tests, including but not limited to, patient and physician demands, problems with correct diagnostics, financial aspects, etc.[20]

In this study, a sizable fraction of the inappropriately performed MRI and CT scans ($n = 1304$) involved the head and neck (23.4%) and the abdominal organs (26.9%).

The bulk ($p = 0.001$) of the $n = 1304$ non-corresponding exams, according to the results, involved GP referrals for head, neck, and abdomen MRI and CT scans. Clinical guidelines advise against imaging tests in persons with isolated headaches due to the low occurrence of severe intracranial disorders (i.e., headache not accompanied by other neurological symptoms). However, a referral for an ambulatory head CT/MRI is frequently required due to the common complaint of headache, which is also one of the most frequent clinical presentations.[21,22]

In 3.3% of cases involving surgeons, erroneously inappropriate referrals for exams of the abdomen organs were detected. In 3.3% of

cases involving specialists, recommendations for unnecessary MRI and CT scans of the chest organs were predominated too.

A significant factor in the development of diagnostic imaging[23] may also be the independent direction in the field of imaging diagnostics. Self-referral imaging is the practice of doctors (or nonphysical service providers) who do not practice radiology and who refer patients to either their own internal imaging services or to external facilities in which they have financial stakes. Non-radiologists who work in practice may be able to increase their income,[24] due to the practice. Although earlier research has demonstrated that less experienced practitioners perform significantly more diagnostic tests, it is currently unknown whether this leads to greater inappropriate usage of imaging services.[25]

However, there is a need for additional research aimed at exploring other factors. For instance, can unwarranted MRI/CT scans help to prevent future health problems? And are there any hidden benefits for health insurance companies?

It is critical to emphasize the significance of conducting a compliance analysis of completed CT and MRI exams at the state level.[26] Several studies highlighted the need of creating protocols to boost the relevance of inquiries about MRI/CT scans by encouraging primary care physicians to understand the proper use of research data, which may lower the number of erroneous referrals to these studies.[27]

In turn, cooperation between the clinician and the radiologist should also be an integral part of this process. Failure to provide accurate information to the radiologist about the referral for an X-ray examination may affect the quality of the final conclusion and diagnosis. Such a situation can be improved through the wider use of modern communication systems between doctors and open databases (health records).[28,29]

To address the issue of the appropriateness of prescribing CT/MRI, it is necessary to develop official guidelines for the optimal use of clinical radiology. So that it can be used by clinicians responsible for the referrals for diagnostic imaging and radiography.

5 | CONCLUSIONS

Our findings indicate an increase in the number of unnecessary referrals for CT and MRI scans over the study period (2014–2019). It has had a major impact on the rise in healthcare costs. The results highlight the necessity for patient education, and widespread application of the guidelines among referring physicians. It demonstrates the need to optimize the use of healthcare funds for improving the quality of diagnostics and disease prevention.

6 | STUDY LIMITATIONS

This study, which had several restrictions, was a retrospective review of referrals for diagnostic testing from medical records. Analysis of these populations reveals important information, demonstrating that inappropriate conduct of diagnostic imaging studies is still significant even though our results may have some limited generalizability to include MRI and CT scans in just two multidisciplinary hospitals in a single large city. difficulty in Kazakhstan.

AUTHOR CONTRIBUTIONS

Dinara Baiguissova: Conceptualization; investigation; resources; supervision. **Andrea Laghi**: Investigation; software; validation; visualization; writing—original draft. **Assel Rakhimbekova**: Conceptualization; formal analysis; methodology; visualization; writing—original draft. **Ildar Fakhradiyev**: Methodology; validation; writing—original draft. **Aigerim Mukhamejanova**: Conceptualization; data curation; formal analysis; investigation; writing—review & editing. **Galina Battalova**: Formal analysis; investigation; methodology; validation; visualization; writing—original draft. **Shynar Tanabayeva**: Methodology; validation; writing—original draft. **Samat Zharmenov**: Investigation; methodology; resources; software; visualization; writing—original draft. **Timur Saliev**: Methodology; visualization; writing—review & editing. **Galina Kausova**: Methodology; resources; validation; writing—review & editing.

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CONFLICTS OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

TRANSPARENCY STATEMENT

The lead author Ildar Fakhradiyev affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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