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Application of Artificial Intelligence in Magnetic Resonance Imaging: Implementation of a Healt Technology Assessment (HTA)

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RESEARCH ARTICLE

Abstract

The implementation of Artificial Intelligence (AI) in Magnetic Resonance Imaging (MRI) represents a significant innovation in the healthcare sector, with potential benefits in terms of both efficiency and diagnostic quality. This study conducted an analysis through a Health Technology Assessment (HTA) model to evaluate the impact of AI on 1.5 T and 3 T MRI scanners, focusing on the reduction of examination acquisition times. The results show a cost-benefit ratio that justifies the investment due to a quick economic return and an increase in departmental productivity. The rise in MRI exams performed contributes to the objectives of Radiology units and hospital management to reduce waiting lists. Furthermore, AI enhances image quality, reducing artifacts and noise, providing superior diagnostic support, and allows for a broader patient base, as faster exams are better tolerated by less compliant patients. Our model thus highlights the numerous advantages of adopting AI in MRI, emphasizing its relevance to the regional and national healthcare system, and its ability to meet the objectives of the Italian National Plan 2024-2026 for improving healthcare services.

INTRODUCTION

Any healthcare system might optimize economic resources towards effective and safe technologies and treatments that adopt scientific advancements and innovation while maintaining economic sustainability. Health Technology Assessment (HTA) is one of the tools capable of guiding decisions towards this virtuous goal [1,2]. HTA is the "multidisciplinary process that synthesizes information on clinical, economic, social, and ethical issues related to the use of a health technology, in a systematic, transparent, impartial, and robust manner" [3,4]. In recent years, among the health technologies employed in imaging diagnostics, Magnetic Resonance Imaging (MRI) has experienced rapid developments, including the implementation of Artificial Intelligence software. We have therefore conducted a hypothetical Health Technology Assessment model on the application of Artificial Intelligence to MRI equipment, identifying numerous potential advantages, including the optimization of image quality, reducing or eliminating artifacts, supporting radiologists in detecting specific pathologies or anomalies, and especially reducing acquisition times for individual exams. This last potential advantage addresses two types of needs: one related to the patient shorter exam duration leads to greater compliance and one related to the healthcare system as a whole more exams per MRI session contribute to reducing waiting lists, a key objective of the National Plan 2024-2026.

This study aims to design a comparison model within the framework of Health Technology Assessment (HTA) between MRI scanners currently in use without the application of AI and the same scanners with potential AI implementation, with the goal of evaluating the impact that such implementation would bring. This model requires the analysis and comparison of various factors to achieve a comprehensive understanding of the issue [5].

To do this, it was necessary to analyze several parameters:

- Costs: the microeconomic level in terms of reimbursement, DRG, purchase, maintenance, and installation; the macroeconomic level in terms of impact on the national healthcare economy, specifically the cost of the exam.
- Effectiveness: evaluation of the differences between MRIs with AI and MRIs without AI in various clinical applications, and assessment of Spatial Contrast Resolution with a focus on Temporal Resolution [6-7].
- Efficiency: evaluation of the benefit/cost/time ratio of the MRI exam.
- Social Impact: patient tolerance in terms of

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MRI exam duration.

Five parameters were also defined, based on which a baseline model was determined. Specifically, the analyzed criteria included:

- Cost of AI in the market (average cost among the main vendors)
- Image quality
- Degree of tolerability of an exam
- Acquisition time for individual exams
- Number of exams per session

The final objective is to develop a HTA evaluation model for AI applied in MRI scanners, which can effectively support healthcare organizations in identifying and evaluating technologies that maximize patient benefits, as well as advantages for the healthcare system, the economy, and society as a whole. In evaluating economic aspects, in accordance with the HTA model, we will subsequently detail:

- Preventive spending with a breakdown of costs
- Benefits in terms of output, outcomes, clinical effectiveness, and served patient base
- Cost analysis, including potential annual savings and economic impacts on other services

MATERIALS AND METHODS

Analysis of preventive spending and cost-effectiveness

Several papers were collected where the main costs (average-list cost of major vendors) regarding the implementation of AI on 1.5T and 3T equipment were analyzed. The prices are indicative as they may vary mainly due to the greater complexity of the algorithms applied to manage the acquired data (the 3T has a greater amount of acquired data compared to the 1.5T), type of AI system required (more sophisticated features and algorithms require higher prices); costs may vary according to the level of customization and integration required to adapt the AI solution to the specific needs of each hospital, integration with existing RIS/PACS systems may incur additional costs, and finally, the request for additional services such as training, support, and upgrades may require additional cost [8-10].

In summary, the ranges shown (Tab.1) reflect the variability in the market and the need to carefully assess the specific needs of each healthcare organization.

Fig.1 shows the remunerations provided for different types of MRI examinations in the tariff schedule of Sicily Region (2024)

Tab.1 *Prices referring to the AI cost of major vendors according to a report by "Signify-Research" (ed.2022) are given. Costs are indicative and may vary based on multiple factors*

VENDORS PRICES				
	IA	Assurance	Technical Support and Maintenance	Technical Staff Training
1.5 T	150.000-250.000	20.000-35.000	20.000-35.000	10.000-20.000
1.5 T	160.000-260.000	22.000-37.000	22.000-37.000	10.000-20.000
1.5 T	150.000-280.000	15.000-25.000	10.000-20.000	___________
1.5 T	170.000-270.000	15.000-20.000	15.000-20.000	5.000-10.000
3.0 T	200.000-300.000	25.000-40.000	25.000-40.000	15.000-25.000
3.0 T	220.000-320.000	27.000.42.000	27.000.42.000	15.000-25.000
3.0 T	200.00-300.000	15.000-25.000	10.000-20.000	___________
3.0 T	200.000-300.000	15.000-20.000	15.000-20.000	5.000-10.000

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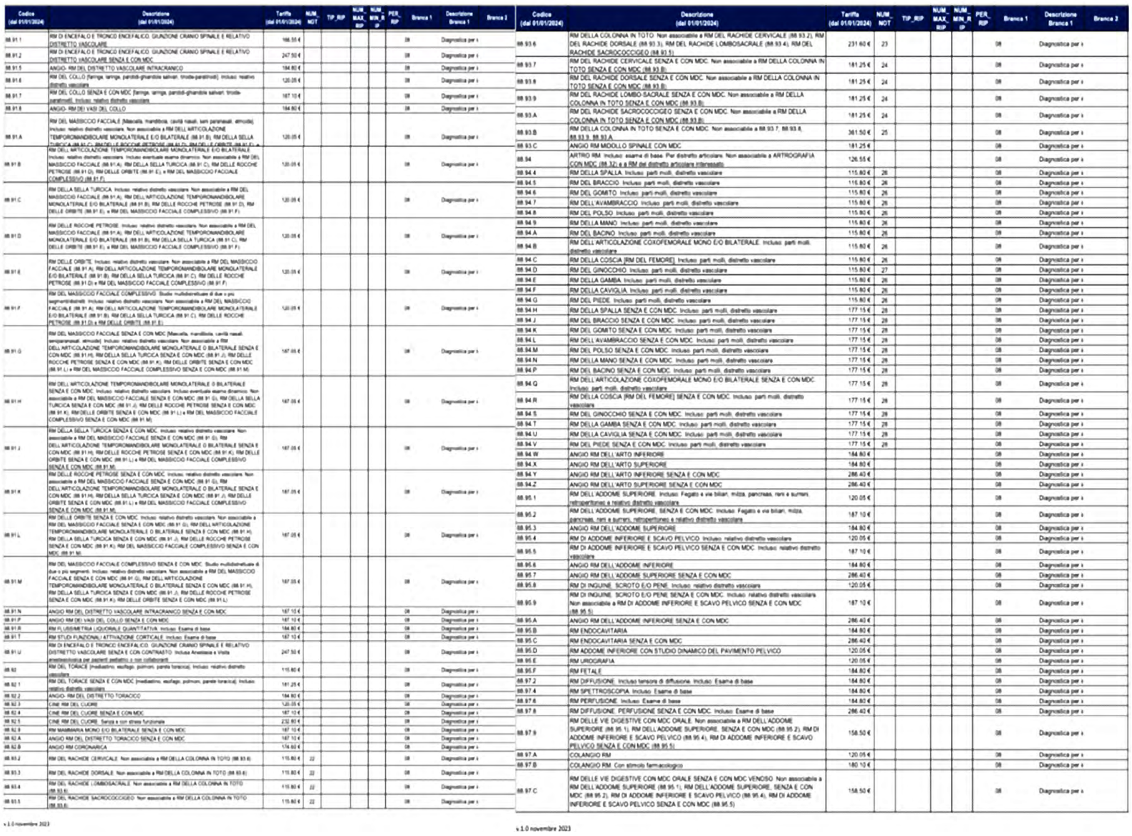

Fig.1 *Sicilian Region outpatient specialty nomenclator 2024*

MR examination: execution times analysis

The table summarizes the execution times of a MRI examination with 1.5T and 3T scanners, respectively, based on different sources of scientific literature without and with the integration of Artificial Intelligence.

Tab.2 *Average acquisition times by body district. Indicative among major vendors, without and with AI*

MR EXAMINATION	*TEMPORAL RESOLUTION SCANNER MRI 1.5T w/o IA*	*TEMPORAL RESOLUTION SCANNER MRI 1.5T With IA*	*TEMPORAL RESOLUTION SCANNER MRI 3.0 T w/o IA*	*TEMPORAL RESOLUTION SCANNER MRI 3.0 T with IA*
MR of the Brain,and Related Vascular District	20-25*min*	10-15*min*	18-20*min*	8-10*min*
MR of the Brain,and Related Vascular District with and w/o Contrast	25-30*min*	12-18*min*	21-23*min*	10-12*min*
MR of the Brain and Angio-MRI of the Intracranial Vascular District	25-30*min*	12-18*min*	21-23*min*	10-12*min*
MRI of the Neck with and w/o Contrast	30-35*min*	20-25*min*	25-30*min*	18-20*min*
MRI Maxillo Facial	30*min*	20*min*	25*min*	15*min*
MRI of the Sella Turcica	40-45*min*	30-35*min*	30-35*min*	20-25*min*
MRI of the Petrous Bones	25-30*min*	12-18*min*	18-20*min*	10-12*min*
MR Orbits With Contrast	30-35*min*	25-30*min*	20-25*min*	18-22*min*
Cardiac MRI Contrast	50*min*	20*min*	40 *min*	20*min*
Breast MRI with Contrast	25-35*min*	16-24*min*	18-20*min*	15*min*

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MR Cervical Spine	20-22*min*	10-12*min*	16-18*min*	10-12*min*
MR Cervical Spine with Contrast	22-24*min*	11-13*min*	18-20*min*	12-14*min*
MR Dorsal Spine	20-22*min*	10-12*min*	16-18*min*	10-12*min*
MR Dorsal Spine with Contrast	22-24*min*	11-13*min*	18-20*min*	12-14*min*
MR Lumbar Spine	22-24*min*	12-14*min*	18-20*min*	12-14*min*
MR Lumbar Spine with Contrast	24-26*min*	12-14*min*	20-22*min*	14-16*min*
MR Total Spine	60-70*min*	40-50*min*	60-70*min*	35-45*min*
MR Total Spine with Contrast	68-78*min*	44-54*min*	65-75*min*	40-50*min*
ARTRO-MRI	20-30*min*	15*min*	20-30*min*	15*min*
MR Shoulder / Contrast	20-30*min*	15*min*	20-30*min*	15*min*
MR Elbow / Contrast	30-35*min*	15-20*min*	20-25*min*	10*min*
MR Hand/Wrist Contrast	30-35*min*	15-20*min*	20-25*min*	10*min*
MR Sacro-iliac joint with Contrast	30-40*min*	15-20*min*	20-30*min*	10-15*min*
MR Sacro-iliac joint	30-40*min*	15-20*min*	20-30*min*	10-15*min*
MR Femoral Contrast	30-35*min*	15-20*min*	20-25*min*	10*min*
MR Knee with Contrast	20-25*min*	10-12*min*	15-20*min*	5-8*min*
MR Ankle/Feet Contrast	30-35*min*	15-20*min*	20-25*min*	10-15*min*
MR Upper Abdomen	20-30*min*	10-20*min*	20-30*min*	10-20*min*
MR Upper Abdomen with Contrast	30-40*min*	15-20*min*	20-30*min*	10-15*min*
MR Abdomen Pelvis	25-35*min*	10-15*min*	15-25*min*	10-15*min*
MR Abdomen Pelvis with Contrast	35-45*min*	15-25*min*	25-35*min*	15-25*min*
MR cholangiography	20-30*min*	10-20*min*	20-30*min*	10-20*min*

Data Analysis and projections

The efficient and productive management of an MRI department is a crucial challenge to ensure high quality care and resource optimization. In this context, we analyzed a hypothetical scenario in which the MRI department is equipped with two scanners one 1.5 Tesla and one 3 Tesla with a highly structured weekly examination schedule management. Hypothetically, we estimated a number of MRI examinations that can be performed during a 12-hour daily shift, considering the different types of examinations expected in an MRI department, in detail, Monday through Saturday: Monday neuro, Tuesday muscle, Wednesday abdomen, Thursday heart, Friday neuro and facial massif, Saturday neck. In addition, we took into account the time needed to position and prepare the patient between examinations (10-15min). Cost analysis took in conconsideration the cost-benefit ratio.

RESULTS

Evaluation of Contrast Resolution (CNR) and Spatial Resolution(SNR)

One of the main benefits of using AI in MRI is the improvement of contrast resolution. With AI, in particular with Deep Learning systems, background noise in images can be effectively reduced, thereby improving the signal-to-noise ratio. This allows images with greater contrast and detail to be obtained, facilitating diagnosis and interpretation by radiologists [11,12]. In addition, AI enables the best use of the temporal resolution of MRI, allowing increased spatial resolution without compromising acquisition time or contrast resolution. Usually, as spatial resolution increases, noise increases proportionally, making image interpretation more difficult. Thanks to the intervention of AI, this problem is overcome, making it possible to obtain high spatial resolution MRI images with excellent contrast resolution free of any kind of artifacts and in low acquisition time [13]. This innovative approach based on the integration of AI in MRI represents an important step in the evolution of diagnostic imaging, offering radiologists more powerful and accurate tools for the analysis and interpretation of MRI images, with positive effects on the quality of diagnosis and patient care [14].

Temporal Resolution

Temporal Resolution, or the ability to acquire images in reduced times, is a key aspect in magnetic resonance imaging (MRI). MRI scanners at 1.5T typically require longer acquisition times than 3T systems because of the lower magnetic field strength. However, the application of artificial intelligence solutions results in a more pronounced reduction in acquisition time in 1.5T scanners than in 3T scanners [15]. This is because AI can more effectively compensate for the limitations associated with the lower magnetic field strength in 1.5T scanners by optimizing image acquisition and reconstruction processes. As a result, the integration of AI in 1.5T scanners achieves higher temporal resolution than 3T systems without such advanced technologies, approaching or even exceeding the temporal performance of conventional 3T scanners. This significant reduction in examination time not only decreases motion artifacts. But it also improves patient compliance and experience, particularly for patients with claustrophobia, dramatically reducing the discomfort and anxiety associated with longer examinations and allowing more people to perform the examination.

MR Studies providable

According to our projections:

- with the 1.5 TMR scanner, with the AI application 113 MR exams would be weekly performed (vs 85 ones without AI),with an increase of 32.94% in MR exams performed
- with the 3MR scanner, with the AI application 137 MR exams would be weekly performed (vs 106 ones without AI), with an increase of about 30% in MR exams performed

Cost Analysis

The implementation of AI in the MRI Imaging process would allow a significant increase in departmental productivity. Based on the data collected, in a year with 312 woking days (excluding Sundays and holidays), the use of AI would allows approximately 1456 and 1612 more MRI examinations to be performed for the 1.5T and 3T scanners, respectively, in comparison with the system without AI, with an increase of 32.94% and 29.25%, respectively. This would correspond to an increase in weekly productivity of 28 (1.5T) and 31 (3.0T) MRI examinations. This would lead, considering the minimum and maximum remunerations according to the actual regional fee schedule, corresponding to 115.8 euros (for spine MRI) and 247.5 euros (for encephalic MRI without and with ev contrast medium), respectively to an increase in annual revenue of approximately 168,604-360,360 euros (average 264,482) with 1.5T scanners and 186,669-398,970 euros (average 292,819) with 3T scanners. Thus, according to the cost-benefit formula, which allows objective quantification of the cost-effectiveness of the technological investment, facilitating adoption decisions by healthcare decision makers.

COST-BENEFIT = BENEFIT-TOTAL/COST-TOTAL

Where:

- Total benefits: represent the total economic value of benefits gained from technology adoption, such as avoided health care costs, additional revenue, etc.
- Total costs: represent the total investment required to adopt the technology, including costs of purchase, implementation, maintenance, etc.

We get:

- Cost-benefit ratio (1.5T) = (168,604 € - 360,360 € in additional revenue) / (150,000 € - 280,000 € initial investment)

= 264.482 € / 215.000 €

= 1.23

Cost-benefit ratio (3T) = (186,660 € - 398,970 € in additional revenue) / (200,000 € - 320,000 € in initial investment)

= 292.819 € / 260.000 €

= 1.12

In addition, considering an estimated initial investment for the adoption of the software with AI of between 150,000-280,000 euros in 1.5T and 200,000-320,000 euros in 3T, this would then be amortized in 1 year of work, following which no additional expenses are expected over and above the

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initial investment, with an imposing and progressive increase in revenues in the years following the year of investment, thus proving to be largely recoverable in the short to medium term.

DISCUSSION AND CONCLUSIONS

The results of our HTA model demonstrate that the application of AI in MRI results in an efficient and effective maneuver on various fronts:

- positive and gradually increasing cost-benefit ratio, particularly after 1 year after the investment, with an increase in the department's productivity;
- the increase in the number of MRI examinations provided by the department contributes to the current goal of the OUs and Hospital Az. Directorates of reducing waiting lists
- Improved image quality and consequent better support for diagnosis
- Increased the pool of patients served: faster examinations are better tolerated by low-compliant patients.

Artificial intelligence represents a revolutionary technology, the application of which in MRI sees many worthy implications of the Health Technology Assessment process and which directly involves health care providers, hospital companies, and the regional and national health care system [16]. Our hypothetical model showed numerous advantages and in particular the possibility of increasing the number of MRI examinations that can be delivered by the hospital company, with the potential to contribute to the achievement of the recent Italian National Plan 2024-2026 goal of reducing waiting lists for diagnostic examinations.

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