Use of artificial intelligence to automatically predict the optimal patient-specific inversion time for late gadolinium enhancement imaging. Tool development and clinical validation

Doctor Torlasco C, Doctor Papetti DM, Doctor Castelletti S, Doctor Sabatini M, Doctor Muscogiuri G, Professor Badano LP, Professor Parati G, Doctor Kellman P, Professor Besozzi D, Professor Nobile MS

IRCCS Istituto Auxologico Italiano, Milan, Italy
University of Milan Bicocca, Milan, Italy
National Heart Lung and Blood Institute, Bethesda, United States of America
University Ca' Foscari, Venice, Italy

Funding Acknowledgements: Type of funding sources: Public grant(s) – National budget only. Main funding source(s): This research was partly funded by the Italian Ministry of Health

Introduction: With the worldwide diffusion of cardiac magnetic resonance (CMR), demand on image quality has grown. CMR late gadolinium enhancement (LGE) imaging provides critical diagnostic and prognostic information, and guides management. The identification of optimal Inversion Time (TI), a time-sensitive parameter closely linked to contrast kinetics, is pivotal for correct myocardium nulling. However, determining the optimal TI can be challenging in some diseases and for less experienced operators.

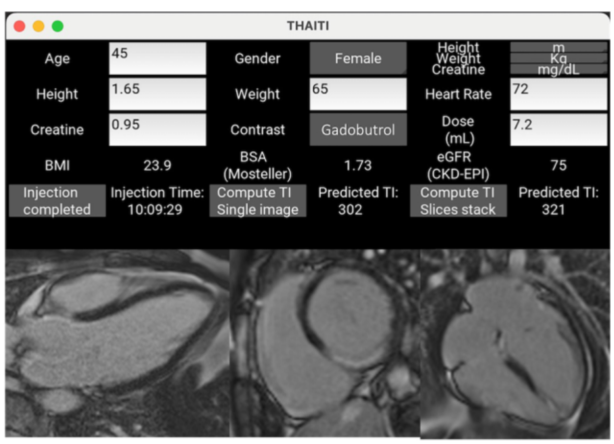
Purpose: To develop and test an artificial intelligence tool to automatically predict the personalised optimal TI in LGE imaging.

Methods: The tool, named THAITI, consists of a Random Forest regression model. It considers, as input parameters, patient-specific TI determinants (age, gender, weight, height, kidney function, heart rate) and CMR scan-specific TI determinants (B0, contrast type and dose, time elapsed from contrast injection). THAITI was trained on 219 patients (3585 images) with mixed conditions who underwent CMR (1.5T; Gadobutrol; averaged, MOCO, free-breathing true-FISP IR [1]) for clinical reasons. The dataset was split with a 90–10 policy: 90% of data for training, and 10% for testing. THAITI's hyperparameters were optimised by embedding k-fold cross validation into an evolutionary computation algorithm, and the best performing model was finally evaluated on the test set. A graphical user interface was also developed. Clinical validation was performed on 55 consecutive patients, randomised to experimental (THAITI-set TI) vs control (operator-set TI) group. Image quality was assessed blindly by 2 independent experienced operators by a 4-points Likert scale, and by means of the contrast/enhancement ratio (CER) (i.e., signal intensity of enhanced/remote myocardium ratio).

Results: In the testing set, the TI predicted by THAITI differed from the ground truth by $\geq$ 5ms in 16% of cases. At clinical validation, myocardial nulling quality did not differ between the experimental vs the control group either by CER or visual assessment, with an overall "optimal" or "good" nulling in 96% vs 93%, respectively.

Conclusions: Using main determinants of contrast kinetics, THAITI efficiently predicted the optimal TI for CMR-LGE imaging. The tool works as a stand-alone on laptops/mobile devices, not requiring adjunctive scanner technology and thus has great potential for diffusion, including in small or recently opened CMR services, and in low-resource settings. Additional development is ongoing to increase generalisability (multi-vendor, multi-sequence, multi-contrast) and to test its potential to further improve CMR-LGE image quality and reduce the need for repeated imaging for inexperienced operators. Figure 1. Top: THAITI interface. Bottom: examples of experimental group CMR-LGE imaging. Table 1. Control vs experimental group. Data expressed as absolute number (%), mean $\pm$ SD, median [IQR]. ‡ T-test; * Chi-square.

Figure 1



38.3 - Artificial Intelligence (Machine Learning, Deep Learning)

Table 1

		Operator-set TI (N = 27)	THAITI-set TI (N = 28)	p
	LGE duration	12:20 ±02:15	12:14 ±02:12	n.s. ǂ
	CMR-LGE images/patient	16 ±3	17 ±3	n.s ǂ
	CMR-LGE - (patients)	8 (30%)	7 (25%)	n.s. *
	TI @first LGE image (ms)	313 ±27	320 ±17	n.s ǂ
	TI @last LGE image (ms)	340 ±25	352±20	0.03 ǂ
	TI range (ms)	[260-390]	[295-400]	
Quality (visual)	**Mag-IR_optimal**	16 (59%)	18 (64%)	n.s. *
	Mag-IR_good	4 (15%)	5 (18%)	
	Mag-IR_sufficient	5 (19%)	4 (14%)	
	Mag-IR_inadequate	2 (7%)	1 (4%)	
	PSIR_optimal	20 (74%)	23 (82%)	n.s. *
	PSIR_good	5 (19%)	4 (14%)	
	PSIR_sufficient	2 (7%)	1 (4%)	
	PSIR_inadequate	0	0	
CER	**CER Mag-IR**	11.9 [6.3-16.0]	11 [7.3-14.3]	n.s ǂ
	CER PSIR	1.2 [1.1-1.3]	1.2 [1.2-1.3]	n.s. ǂ