CATCH-220: Delivering Comprehensive Brain MRI in Under Four Minutes Using Deep Learning Reconstruction at 1.5T

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Abstract

We present in this article the CATCH-220 protocol, which enables full multiparametric brain assessment, including diffusion, susceptibility, and perfusion imaging, within 219 seconds. Integration of deep learning-based reconstruction allows substantial scan time reduction while preserving image quality and diagnostic confidence. The protocol is compatible with standard 1.5T systems and relies primarily on commercially available sequences, supporting scalability across institutions. Ultrafast acquisition may improve MRI accessibility in time-sensitive conditions such as acute stroke, while also facilitating repeated imaging and examinations in non-compliant patients, including pediatric populations.

Introduction

Magnetic resonance imaging (MRI) continues to evolve rapidly, driven by technological innovations that are expanding its clinical capabilities and accessibility [1]. Among these, the integration of artificial intelligence, particularly deep learning (DL), has introduced substantial improvements, not only in post-processing and lesion detection, but also in the acquisition and reconstruction phases of imaging [2, 3]. These advances are now enabling a new generation of ultrafast MRI protocols capable of significantly shortening scan times without compromising diagnostic performance.

The need for faster MRI acquisitions is especially evident in time-sensitive clinical settings [4]. Acute ischemic stroke (AIS) is a paradigmatic example where imaging plays a central role in diagnosis and treatment decision-making [5, 6]. Despite its superior tissue characterization, MRI has traditionally been limited in this context, due to longer acquisition times compared to computed tomography (CT). As a result, efforts have increasingly focused on bridging this gap by developing ultrafast MRI protocols that can approach the temporal efficiency of CT-based workflows [7, 8].

However, the relevance of accelerated MRI extends beyond emergency scenarios. In several clinical contexts, including longitudinal monitoring and populations with limited compliance, reducing scan duration is equally critical. For instance, patients undergoing anti-amyloid therapies for Alzheimer's disease require repeated MRI examinations to monitor amyloid-related imaging abnormalities (ARIA), making efficiency a key determinant of feasibility. Similarly, in pediatric[1] imaging, shorter protocols can mitigate motion artifacts and reduce the need for sedation while preserving the advantages of radiation-free imaging [9–12].

Within this framework, we propose the CATCH-220 protocol (Critical Assessment of Tissue and Cerebral Hemodynamics — 220 seconds), a DL-enhanced, ultrafast whole-brain MRI protocol designed for clinical deployment on standard 1.5T systems. The protocol combines multiple essential contrast weightings, including perfusion imaging, in a total acquisition time of less than 220 seconds.

[1] MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.

Materials and methods

Imaging protocol

The CATCH-220 protocol was developed and implemented on a 1.5T clinical MRI system (MAGNETOM Sola; Siemens Healthineers, Erlangen, Germany) at the "Federico II" University Hospital in Naples, Italy. The system is equipped with a 20-channel head and neck coil and vendor-specific DL-based reconstruction tools (Deep Resolve). In addition, a DL-based 3D echo-planar susceptibility-weighted imaging (EPI-SWI) research sequence[2] was incorporated.

Although optimized on this specific platform, the protocol design is conceptually transferable to other systems.

The protocol includes the following sequences:

i) T1-weighted 2D turbo spin echo (TSE) for structural assessment
ii) T2-weighted 2D TSE and fluid-attenuated inversion recovery (FLAIR) sequences for parenchymal evaluation
iii) Diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) maps for detecting diffusion restriction
iv) DL-based SWI for hemorrhagic and mineralization assessment
v) Perfusion-weighted imaging (PWI) for hemodynamic evaluation

All sequences provided full brain coverage with slice thickness ≤ 5 mm. DWI was acquired using a 2D EPI sequence with three diffusion directions and b-values of 0 and 1000 s/mm². SWI images were reconstructed from a 3D EPI acquisition combining magnitude and phase information, while PWI was obtained using a 2D EPI sequence during administration of a gadolinium-based contrast agent.

Detailed acquisition parameters are reported in Table 1.

Acceleration strategy

Scan time reduction was primarily achieved by integrating DL-based reconstruction techniques. The TSE and DWI sequences were accelerated using Deep Resolve, enabling denoising and resolution enhancement directly in *k*-space [13]. For the SWI sequence, a DL-based super-resolution approach was applied, including interpolation with a factor-of-two increase in spatial resolution [14, 15].

Image acquisition and evaluation

Following protocol optimization, imaging was performed on eight volunteers using the described 1.5T system. When PWI was included, a gadolinium-based contrast agent (Gadobutrol, Gadovist, Bayer AG, Leverkusen, Germany) was administered at a dose of 0.1 mmoL/kg according to standard clinical practice.

To explore reproducibility across sites, the protocol was also implemented on a comparable scanner at an external institution (Bambino Gesù Children's Hospital, IRCCS, Rome, Italy), where two additional scans were successfully acquired.

Image quality was assessed in consensus by two board-certified neuroradiologists (EG and SC), with more than 5 and 10 years of experience, respectively, using a 5-point Likert scale.

All participants provided written informed consent in accordance with the Declaration of Helsinki. Given the technical nature of the study, formal ethics committee approval was not required.

Sequence	Technique	TA (min:sec)	Resolution (mm³)	No. of slices/gap (%)	TR/TE/TI (msec)
T1-weighted	2D-TSE	00:28	0.6 × 0.6 × 5	25/10	500/8.40
T2-weighted	2D-TSE	00:30	0.5 × 0.5 × 5	25/10	4780/105
FLAIR	2D-TSE	00:49	0.6 × 0.6 × 4	30/10	7400/110/2286
DWI	ss 2D-EPI SE	00:16	1.0 × 1.0 × 5	24/30	1800/69
SWI	ms 3D-EPI GRE	00:25	1.0 × 1.0 × 5	30/n.a.	80/50
PWI	ss 2D-EPI GRE	00:53	1.0 × 1.0 × 5	20/20	1600/40

Table 1: Acquisition parameters of the CATCH-220 protocol
All sequences were acquired with transversal slice orientation. The DWI scans were acquired with two b-values (0 and 1000 sec/mm²) and with 3-scan trace.
TA = acquisition time; TR = repetition time; TE = echo time; TI = inversion time; TSE = turbo spin echo; FLAIR = fluid-attenuated inversion recovery; DWI = diffusion-weighted imaging; EPI = echo planar imaging; ss = single-shot; SE = spin echo; SWI = susceptibility-weighted imaging; ms = multishot; GRE = gradient echo; PWI = perfusion-weighted imaging

[2] *Work in progress. The application is currently under development and is not for sale in the U.S. and in other countries. Its future availability cannot be ensured.*

Results

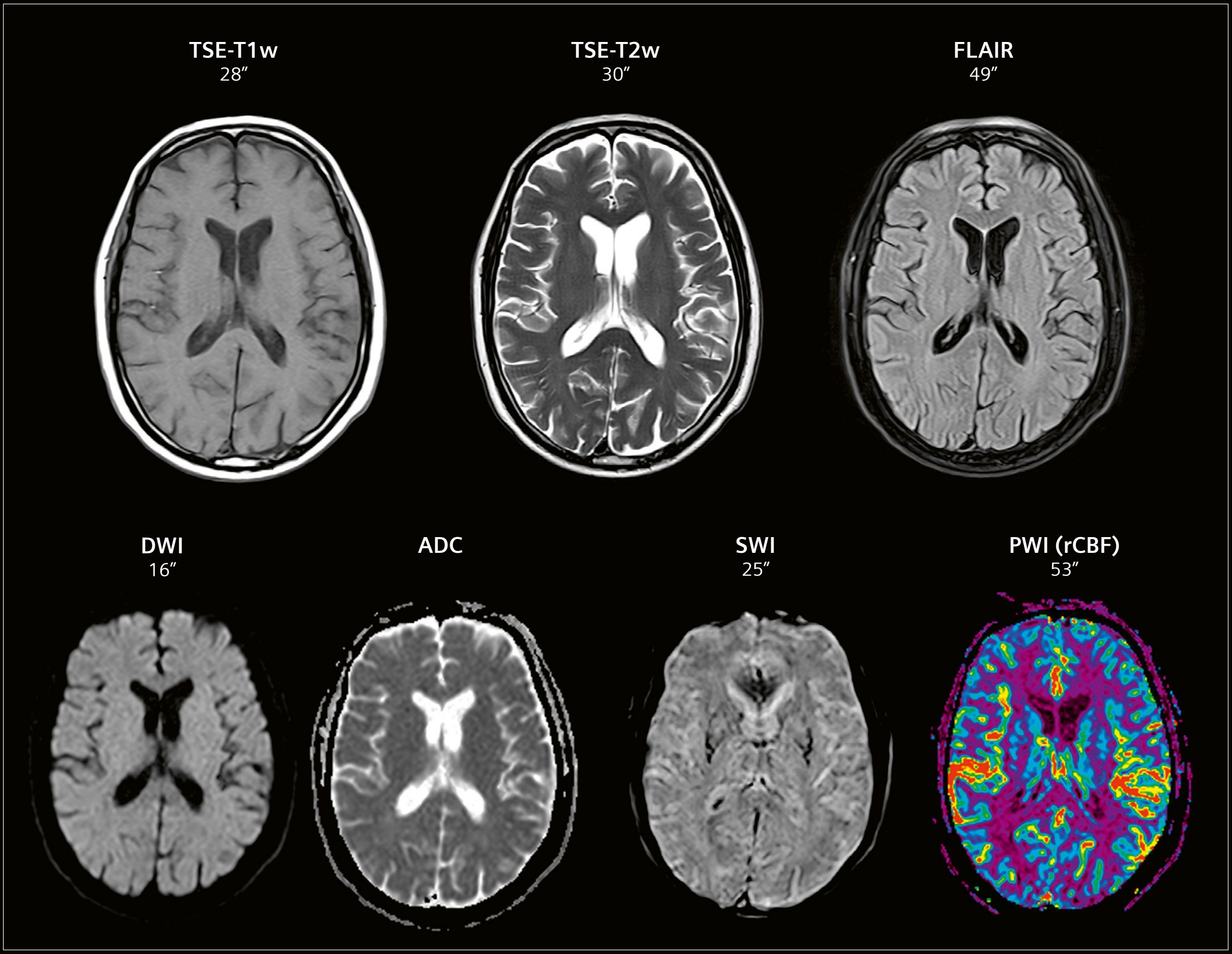
The complete CATCH-220 protocol was successfully acquired in 219 seconds (3 minutes and 39 seconds). Individual sequence acquisition times ranged from 16 seconds for DWI to 53 seconds for PWI. A detailed breakdown is provided in Table 1.

Across all sequences, image quality was consistently rated as excellent. High Likert scores were observed for all contrast weightings, reflecting stable performance in anatomical detail, contrast definition, and signal-to-noise ratio. Representative images are shown in figures 1–3.

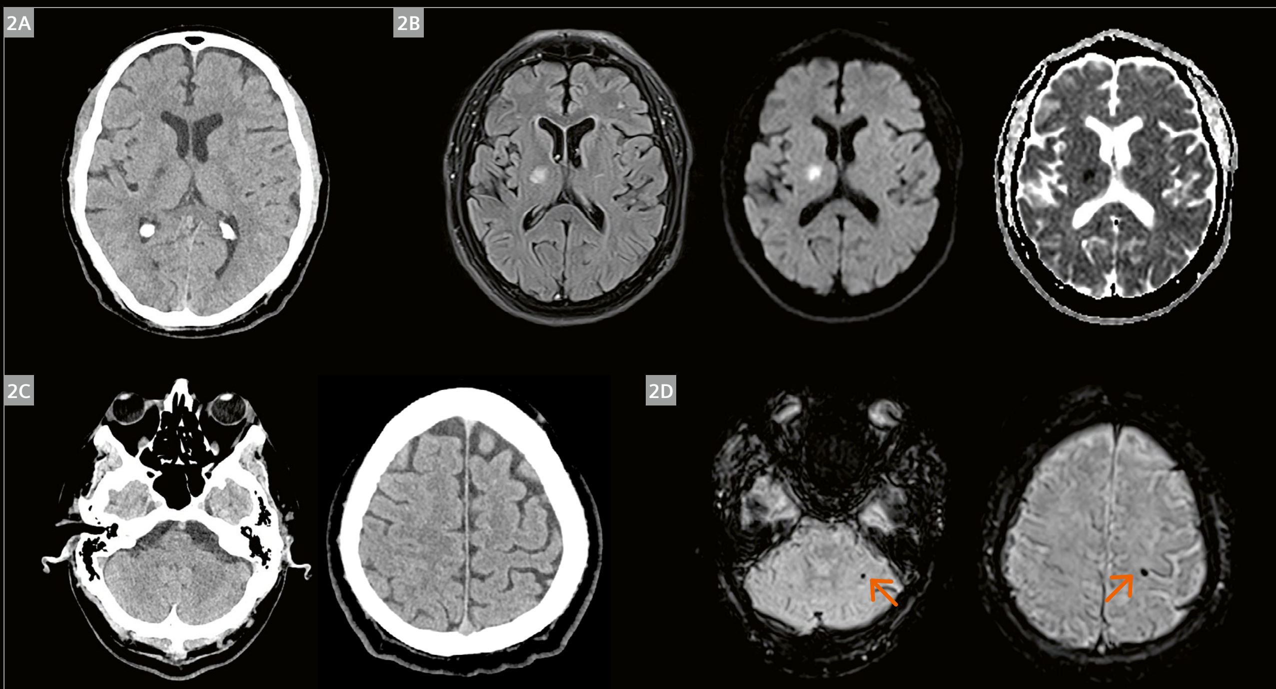
Discussion

This study presents an ultrafast, DL-enhanced MRI protocol capable of delivering a comprehensive whole-brain assessment — including structural, diffusion, susceptibility, and perfusion imaging — in less than four minutes.

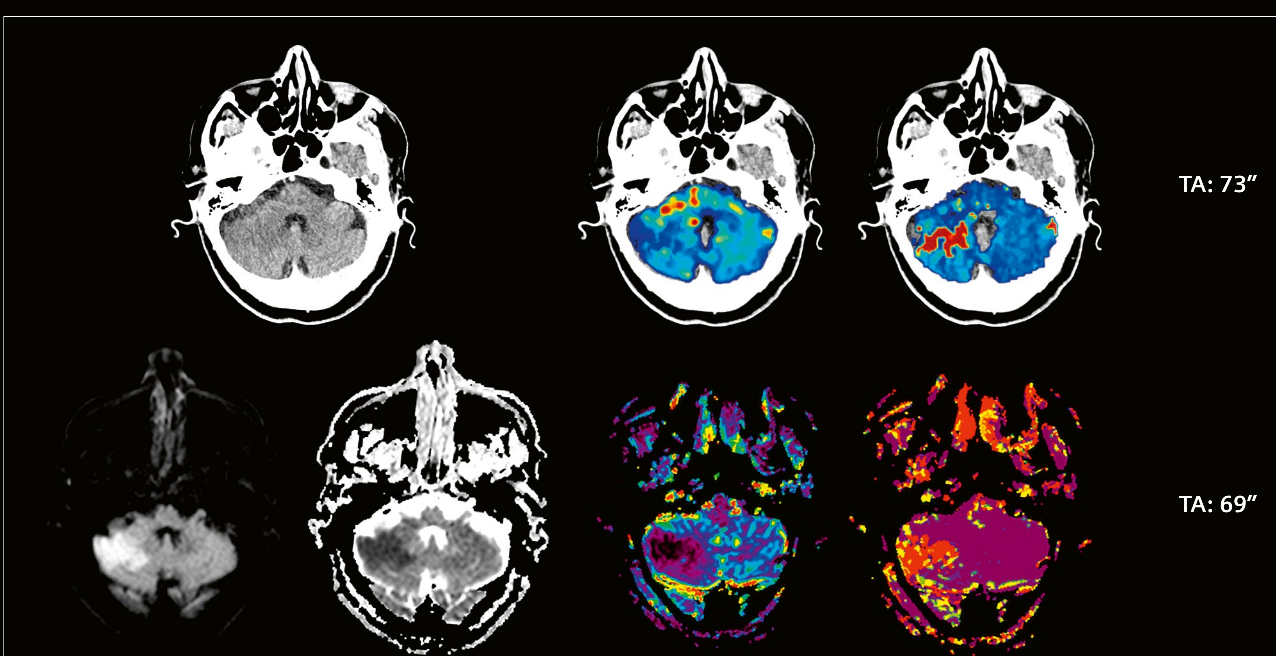
A key strength of the CATCH-220 protocol lies in its compatibility with standard 1.5T systems, which remain the most widely available MRI platforms worldwide [16]. By leveraging commercially available DL-based reconstruction tools, the protocol offers a practical and scalable approach to accelerating MRI workflows. With



1 Representative images from the CATCH-220 protocol.
All sequences included in the CATCH-220 protocol are shown with their respective acquisition times (in seconds). The set comprises T1- and T2-weighted turbo spin echo, T2-FLAIR, DWI with ADC map, SWI, and DSC-PWI sequences. TSE = turbo spin echo; T1w = T1-weighted; T2w = T2-weighted; FLAIR = fluid-attenuated inversion recovery; DWI = diffusion-weighted imaging; SWI = susceptibility-weighted imaging; PWI = perfusion-weighted imaging; rCBF = regional cerebral blood flow; ADC = apparent diffusion coefficient; DSC = dynamic susceptibility contrast.



2 Example of CATCH-220 acquisition in a clinical case.
A 65-year-old male with a subacute cerebrovascular event involving the right internal capsule: The lesion, barely visible on baseline CT **(2A)**, is clearly delineated on MR sequences (**2B**: FLAIR, b1000, ADC). In the same patient, two microbleeds undetected on CT **(2C)** are revealed on SWI (**2D**, orange arrows). CT = computed tomography; MR = magnetic resonance; FLAIR = fluid-attenuated inversion recovery; ADC = apparent diffusion coefficient; SWI = susceptibility-weighted imaging.



3 Comparison between CT and MR in an ischemic stroke patient.
A 78-year-old female with acute ischemic stroke of the posterior circulation: Basal CT shows subtle cerebellar gray–white matter blurring with reduced rCBF and increased Tmax. (Top row) DWI from the CATCH-220 protocol confirms and better delineates the lesion, while PWI maps (rCBF, Tmax) define core and penumbra. (Bottom row) DSA (not shown) confirmed basilar tip occlusion. CT = computed tomography; MR = magnetic resonance; rCBF = relative cerebral blood flow; Tmax = time to maximum; DWI = diffusion-weighted imaging; PWI = perfusion-weighted imaging; DSA = digital subtraction angiography

the exception of the SWI sequence, all components are already available as product sequences, supporting potential translation into routine clinical practice.

The inclusion of perfusion imaging is a notable aspect of this protocol. To our knowledge, few ultrafast MRI approaches have integrated PWI within such a limited acquisition time. This feature enables assessment of the DWI–PWI mismatch, a well-established marker in AIS that is often underused due to time constraints [17, 18]. By reducing acquisition time, the protocol may facilitate broader use of perfusion imaging in acute settings, where it remains clinically relevant. In light of its inclusion in recent guidelines [19], PWI may regain a more central role in stroke imaging, provided that acquisition becomes time-compatible with acute workflows. Recent years have seen a growing application of AI in various aspects of ischemic stroke diagnosis and patient stratification [20], and we believe that these innovations have the potential to redefine the role of MRI in AIS, by enabling fast, comprehensive, and high-resolution assessments even in hyperacute phases.

Beyond acute stroke, the potential applications of CATCH-220 extend to other clinical scenarios. In longitudinal imaging, such as ARIA monitoring in patients receiving anti-amyloid therapies, shorter scan times may improve adherence and workflow efficiency [9–11]. Similarly, in pediatric and non-cooperative populations, ultrafast protocols can reduce motion artifacts and minimize the need for sedation [12].

Nevertheless, some limitations should be acknowledged. The protocol does not include a dedicated angiographic sequence, such as time-of-flight (TOF) MR angiography (MRA), which could limit its immediate applicability in certain vascular contexts [21]. Although SWI may provide indirect information through markers such as the susceptibility vessel sign [22, 23], it cannot fully replace vascular imaging yet.

In conclusion, we propose CATCH-220 as a DL-enhanced, clinically implementable ultrafast MRI protocol that enables comprehensive whole-brain imaging in less than 220 seconds. By combining multiple contrast weightings, including perfusion, within a single rapid acquisition, the protocol offers a flexible and scalable solution for a wide range of neuroradiological applications. Its compatibility with standard 1.5T systems and reliance on commercially available tools support its potential integration into routine clinical workflows, particularly in scenarios requiring rapid imaging or repeated examinations.

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