MRI quality data assessment in the Italian IRCCS advanced neuroimaging network using ACR phantoms

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Synopsis

Generating big-data is becoming imperative with the advent of machine learning. Neuroimaging networks respond to this need. Italian Research Neurological Institutes have formed an advanced neuroimaging network to develop protocols for multisite studies. The present work reports on ACR phantom data across sites and evaluates accuracy and longitudinal reproducibility of: uniformity and ghosting, geometric accuracy, slice thickness, high-contrast and low-contrast object detectability. Our findings show that uniformity, geometric accuracy, low-contrast object detectability are measures that failed at some sites. We intervened to correct these issues improving protocol quality and scanner stability, establishing levels of precision relevant for future multicentre studies in quantitative imaging.

Introduction

Big data is the new frontier of innovation. The need of analyzing large amount of data is becoming fundamental in many fields to improve efficiency, quality and prediction of results. An important example is the healthcare domain. Indeed, in the last years, several neuroimaging networks comprising numerous centers all over the world have been formed to collect, put together and share big amount of data (1,2). In this context, the Italian IRCCS advanced neuroimaging network* was born with the support of the Italian Ministry of Health (RRC-2016-2361095; RRC-2017-2364915) to share common MRI protocols and evaluate the performances of each MRI scanner that is part of the network for future multisite and multivendor studies. The network is composed of twenty-two sites distributed all around Italy. Each one has been involved in multiple tasks, ranging from technical to clinical skills. The aims of this work were: 1) to implement and optimize the standardized American College of Radiology (ACR) protocol (3); 2) to evaluate the accuracy and reproducibility of different geometrical and contrast measures using ACR phantoms across sites and vendors; 3) to evaluate the longitudinal reproducibility of these phantom measures.

Methods

<u>Phantom:</u> After a benchmarking of different available phantoms, two were selected: ACR large and ACR small, selected according to the dimension of the head-coil used at each site.

<u>IRCCS sites:</u> Sixteen of the twenty-two sites have a 3T scanner; for the longitudinal analysis, fourteen sites that acquired at least 4 time points were included. The scanner vendors included General Electric, Philips, and Siemens. Details of the scanner and head-coil used at each site are reported in Table1.

<u>Acquisition protocol:</u> Starting from the standardized ACR protocol (3) that includes T1w/T2w images, sequence parameters were adapted as follow: acquisition matrix was modified to obtain an in-plane isotropic voxel (ACR small), post-processing filters were disabled and receiving bandwidth was set at 250±20Hz/px. The protocol was implemented at three sites, one for each vendor, and distributed to the remaining centers.

<u>ACR analysis:</u> Two different software were tested for data analyses: a commercial software, Radia (https://radimage.com/products/rit-family-of-products/diagnostic), and a semi-automatic quality assurance (SAQA) Matlab script (http://jidisun.wixsite.com/osaqa-project/resources). The following tests were performed and standard ACR tolerance range was considered: analysis of uniformity and ghosting, geometric accuracy, slice thickness, high-contrast and low-contrast object detectability (Fig1).

Scanners were considered longitudinally not stable if the same test failed at least at two consecutive time points.

Results

Our findings showed that the SAQA script is more flexible (it can be easily modified) and less user-dependent than Radia, thus all analyses were performed using the SAQA script.

ACR small: all sites passed all tests except site 6B that failed, longitudinally, the slice thickness measure (Fig2).

ACR large: all sites passed the ghosting and slice thickness tests, while for the other tests at least one site highlighted some problems in one or more time points (Fig3). In detail, two sites (2 and 6A) failed the uniformity test and one site (6A) failed the low-contrast object detectability test in at least two consecutive time points. Furthermore, two sites (8A in 3 time-points, and 13 in 1 time-point) failed the geometric accuracy test (Fig4).

Discussion

The Italian IRCCS neuroimaging network is the first large neuroimaging network in Italy and the present work demonstrates how good synergy between sites can improve scientific impact of each involved center.

The network is composed of many vendors, different software releases and, in some cases, different types of coils. All these variables affect the sequences output and consequently the harmonization pipeline. This exercise also allowed us to enhance the original ACR scanning procedure by limiting additional software and hardware confounding factors that could affect quantitative imaging (3).

For example, our tests showed that the slice thickness measure seemed to be affected by the number of coil channels and suggested a possible intervention to tune their gains. Furthermore, the geometric accuracy test highlighted a significant deformation along the cranio-caudal direction in certain sites, suggesting the necessity to tune the scanner gradients. Moreover, geometric accuracy and low contrast tests gave indications about possible B0 inhomogeneities (e.g. imperfect shim or a gradient miscalibration) and a low SNR (4).

In conclusion, setting up this procedures with the ACR phantoms have identified sites performing below acceptable image quality levels. Thanks to the technical expertise available at network level, each site was supported to correct their specific issues, improving the quality of own protocols and understanding the importance of checking scanner stability over time, essential for quantitative in vivo neurological studies.

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Figures

Site	Field	Vendor	Model	Software release	Head-coil (channels)	ACR Phantom
Site 1	3T	GE	Discovery MR750	DV24	32	Large
Site 2	3T	GE	Signa HDxt Twin Speed	15.0_0947a	8	Large
Site 3	3T	GE	Discovery MR750	DV26.1	8	Small
Site 4	3T	Siemens	Verio	--	8	Large
Site 5	3T	Siemens	Skyra	VD13A	32	Small
Site 6A	3T	Siemens	Skyra	VE11	20	Large
Site 6B	3T	Siemens	Skyra	VE11	64	Small
Site 7	3T	Siemens	Skyra	VE11	32	Small
Site 8A	3T	Philips	Achieva	5.3.0.3	32	Large
Site 8B	3T	Philips	Achieva	5.3.0.3	32	Small
Site 9	3T	Philips	Achieva dStream	5.3.0.3	32	Large
Site 10	3T	Philips	Achieva	5.1.7	32	Large
Site 11	3T	Philips	Ingenia CX	5.3.0.3/5.4	32	Large
Site 12	3T	Philips	Achieva	3.2.3	32	Large
Site 13	3T	Philips	Achieva/Achieva dStream	3.2.3.4	32	Large
Site 14	3T	Philips	Ingenia CX	5.3.0.3	32	Large
Site 15	3T	Philips	Achieva	3.2.3	32	Large
Site 16	3T	Philips	Ingenia	5.3.0.3	32	Small

Table 1: Scanner and phantom information for each site of the Advanced neuroimaging network of Italian research neurological institutes (IRCCS).

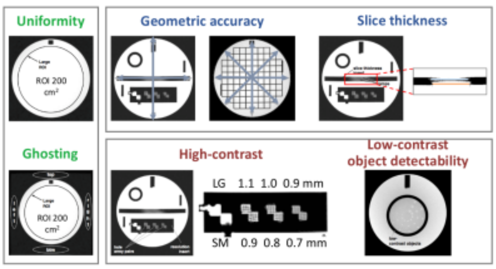

Figure 1: ACR tests. The scanner uniformity and ghosting tests are reported in the left panel, the geometric tests in the top panel and the image contrast tests in the bottom panel.

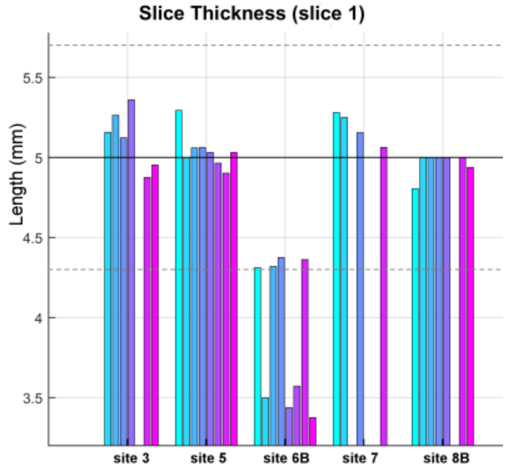

Figure 2: ACR small: comparison among centers on slice thickness measure. Solid line represents actual phantom length while dot lines identify tolerance range.

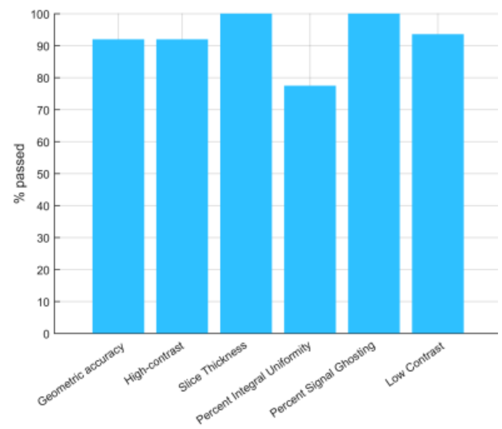

Figure 3: ACR large: percentage of sites that have passed each quantitative test.

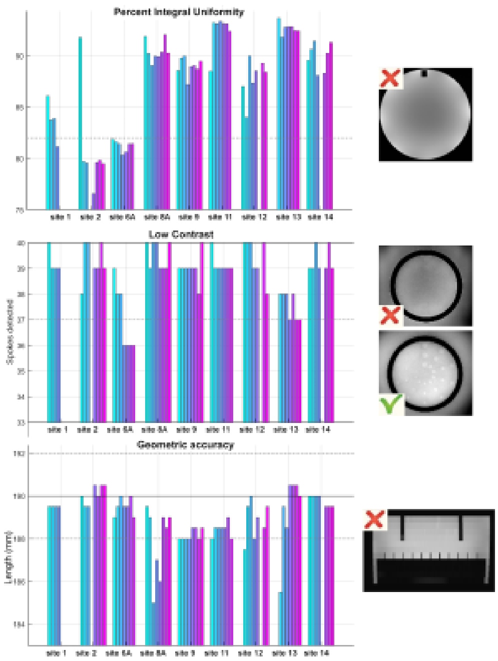

Figure 4: ACR large. On the left: comparison among centers on uniformity (top), low-contrast (middle), and geometric accuracy (bottom) tests. Solid line represents actual phantom features (length and number of detectable objects) while dot lines identify tolerance range. On the right: example of failed tests for each quantitative measure.