Independent Factors Which Impact Image Quality in Carotid Vessel Wall Imaging: Implications for Multi-center Studies

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Introduction: Carotid vessel wall imaging has been successfully conducted at a variety of institutions in both the research and clinical settings.[1,2] Despite advances in coil technology to improve image quality (IQ),[3] obtaining consistently good IQ across all subjects and imaging sites remains a challenge. For example, in one study utilizing six different imaging centers only two-thirds of participants had sufficient IQ for interpretation[2]. In our own experience, we have seen that images acquired from a partner institution in China frequently have better IQ than those from our own center. Though subject motion and artery depth have been identified as major causes of poor IQ,[2,4] additional patient characteristics that have been heretofore unrecognized may also adversely affect IQ. The identification of factors that govern IQ within and between sites would be valuable in broadening the utility and clinical acceptance of carotid MRI. As such, in this study we sought to identify specific patient characteristics associated with IQ and determine potential causes of IQ disparity between imaging sites.

Methods: Subjects who underwent carotid MRI with asymptomatic carotid artery stenosis (assigned as the index side) were retrospectively selected at our site in the U.S. (N=46) and our partner site in China (N=34). Age, gender and body mass index (BMI) were recorded before each scan. *MRI protocol:* Both sites used a 3.0 T whole-body scanner (Achieva, Philips, Netherlands) and eight-channel phased-array surface coils. Subjects at both sites were imaged with an identical black-blood (QIR)[5] TSE sequence using identical parameters (TR/TE = 800/10ms, ETL = 10, NEX = 1, matrix = 256×250, FOV = 14×14 cm). *Image review:* Images were analyzed (index side only) by one reader blinded to site and demographic information. The signal-to-noise ratio of fibrous tissue in the arterial wall (SNR_w) was measured on one axial slice at the carotid bifurcation. SNR_w was calculated as: $SNR_w=\sqrt{(S_s^2 - S_n^2)}/(SD_n/0.707)$, where S_s is the mean signal intensity of fibrous tissue, S_n and SD_n are the mean and standard deviation of the background noise and 0.707 is the correction factor for eight elements.[6,7] Artery depth was measured as the minimum distance from the carotid bifurcation to the skin on axial images. Neck diameter was measured as the transverse skin-to-skin distance through the bifurcation (recorded as 14.0 cm if it exceeded FOV). Subject motion was recorded as presence/absence of motion artifacts (i.e. ghosting of tissue and/or blurring of edges). *Statistical analysis:* Univariate and multivariate associations with SNR_w were evaluated using Generalized Linear Models (GLMs).[8] Regression results are presented as percent change in average SNR_w (%ΔSNR). To make effect sizes more interpretable between continuous variables with different units, the regression coefficients were rescaled to approximately 1/5th of the range of the corresponding variable.

Results: Univariate analysis identified site, BMI, artery depth, neck diameter and motion as having a significant effect on SNR_w (Table 1). However, multivariate analysis selected only motion (Figure 1) and BMI as independently associated with SNR_w. Since BMI was a previously unrecognized predictor of SNR, additional analyses were done to explore the relationship between BMI and IQ. Although BMI was correlated with artery depth (Pearson's r = 0.54, p<0.001) and neck diameter (r = 0.59, p<0.001), the effect of BMI on IQ was still significant after adjusting for both depth and diameter (%ΔSNR / 5kg/m^2 = -21.0, p = 0.001), suggesting effects of BMI extend beyond the expected effects on SNR_w associated with increased neck thickness and deeper arteries. Regarding differences between the two study sites, there were significant differences in SNR_w, age and motion (Table 2). While the SNR_w differences between sites remained significant after adjusting for demographics, artery depth and neck diameter, it was no longer significant after adjusting for motion alone or along with the other variables (p = 0.14 and 0.13, respectively).

Table 1. Effects of potential factors on SNR_w from univariate analysis.

	%ΔSNR	p
Site: U.S. vs. China	-24.5	**0.011**
Age / decade	-3.93	0.400
Gender: male	-10.8	0.328
BMI / 5 kg/m^2	-25.6	**<0.001**
Artery depth / cm	-21.5	**<0.001**
Neck diameter / cm	-12.0	**<0.001**
Motion: presence	-34.1	**<0.001**

Table 2. Demographics, body habitus and presence of motion artifacts by study site.

	Mean±SD or %		
	U.S. (n=46)	China (n=34)	p*
Age (years)	71.5±9.3	65.7±12.2	**0.018**
Gender (male)	63.0	82.4	0.081
BMI (kg/m^2)	27.5±4.6	26.1±2.8	0.114
Artery depth (mm)	33.5±9.3	33.1±7.2	0.863
Neck diameter (mm)	122.6±15.6	125.1±11.7	0.440
Motion (presence)	69.6	29.4	**0.001**

* Unpaired t-test or Fisher's exact test.

Discussion: The significant effect of subject motion on IQ of carotid MRI was confirmed in the combined population. Subject motion was found to be the primary reason for the IQ disparity between the two sites rather than demographics or body habitus, though why motion was a more common phenomenon at the U.S. site is unclear. The effect is unlikely a consequence of site experience or technical issues as both sites have extensive experience in carotid MRI and identical scanners, coils and sequences were used for image acquisition. In accord, techniques for preventing or compensating for motion may be an attractive research target for improving site-to-site consistency. Establishing a standard patient coaching protocol, further development of efficient motion navigators,[4] or both may represent viable approaches to yield consistent IQ. In fact, the data described herein strongly indicate that these approaches may be more beneficial than development of new coils designed to only improve SNR. An unexpected finding was the association between BMI and IQ, which could not be entirely attributed to coexisting deep arteries or thick necks. The etiology of this association is unclear and attempting to identify causality from the current study would be purely speculative. As such, further study is needed to clarify this relationship and should include consideration of automatic scanner settings that may impact gain and RF saturation.

Conclusion: Amongst demographic, anatomic and physiologic variables that may affect IQ during carotid MRI, motion has the greatest impact on IQ. Strategies to reduce patient movement during image acquisition may afford the best opportunity to provide consistent IQ between patients and imaging centers. In so doing, the clinical translation of carotid MRI may be accelerated.

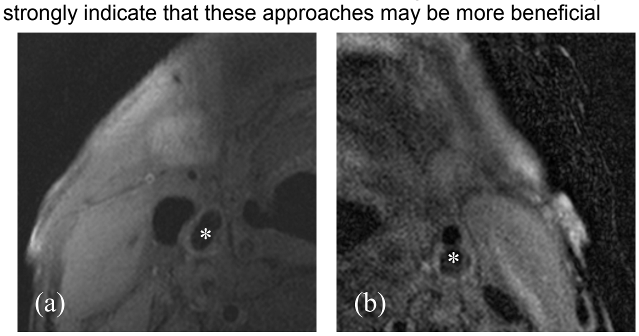

Figure 1. Axial images of carotid bifurcation. Asterisks indicate carotid lumen. (a) 71 year old male from China, artery depth 34.5 mm, BMI 30.1 kg/m^2. (b) 79 year old male from U.S., artery depth 31.4 mm, BMI 29.3 kg/m^2.

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