International Journal of Cancer Therapy and Oncology
www.ijcto.org

Doppler string phantom for assessment of clinical doppler ultrasound velocity measurement

Yi Zhang[1], Ted Lynch[2], Nicholas J Hangiandreou[1]

[1]*Department of Radiology, Mayo Clinic, Rochester, Minnesota, USA.*
[2]*Computerized Imaging Reference Systems, Inc, Norfolk, Virginia, USA.*

Received March 19, 2014; Published Online April 08, 2014

[Presented at the Young Investigator's Symposium at the 2014 Annual Meeting of Southwest Chapter of American Association of Physicists in Medicine (AAPM) in San Antonio, Texas, USA]

Conference Proceeding

Abstract

Purpose: The Doppler string phantom provides accurate velocity of the string motion; it can be used to calibrate Doppler ultrasound (US) velocity measurements and to evaluate variations due to intrinsic spectral broadening. We developed a semi-automated method to estimate the mode velocity (Vmode) and peak velocity (Vmax) based on duplex US images from a string phantom, and use them to assess clinical Doppler US velocity measurement.

Methods: Steady motion of a rubber O-ring (20 – 110 cm/s) in a CIRS Doppler String phantom (Model 043) was studied using GE LOGIQ E9 system with a 9L probe. 5 s of Doppler spectral data was averaged to generate a mean spectral profile. It was fitted by a Gaussian function and Vmode was defined as the velocity of the Gaussian peak, while Vmax is defined as the velocity at which the spectral profile falls to within 1 SD of the background. Vmode and Vmax were evaluated against the prescribed motor velocity. Repeatability and variation to scanning parameters were analyzed and reported in % range, i.e. (max – min) / mean.

Results: Vmode and Vmax had good repeatability over six days (6.0% for Vmode, 2.9% for Vmax). Gain, compression, scale, sample volume (SV) depth and length, frequency and beam steering all had minimal impact on Vmode and Vmax (variations ≤ 4.4%). Doppler angle θ had minimal effect on Vmode (2.2%) but a strong effect on Vmax (26% increase as θ increased from 10° to 60°). Vmode was linearly correlated with but overestimated the motor velocity (Pearson's r = 1.05, $R^2 = 1$).

Conclusion: This study developed a simple yet robust Vmode and Vmax estimation method. Combined with a string phantom, these velocity estimators are shown to be a useful tool to evaluate clinical Doppler US system performance. For the tested system, only Doppler angle has an appreciable impact on Vmax estimation.

Innovation and Impact: Our study presents a novel method to extract mode velocity (Vmode) and peak velocity (Vmax) based on the ultrasound (US) Duplex image exported from the scanner. Combined with a string phantom with known motion velocity, these velocity estimators can be used to calibrate Doppler US velocity measurements and to evaluate measurement variations due to intrinsic spectral broadening (ISB) that can be varied among scanning parameters, machines and manufacturers.

Key Results: Duplex images of a string phantom with steady motion were acquired (**Figure 1**). 5 s of spectral data was averaged to generate a mean spectral profile, which had a smooth and symmetric profile at high velocities but was contaminated with "velocity side - lobe" artifact at low velocities (**Figure 2**). To overtime this artifact, Gaussian fitting was performed, upon which Vmode and Vmax can be estimated. Vmode was highly correlated with but overestimated the prescribed motor velocity.

Different thicknesses (2 and 4 cm) of tissue - mimic material (TMM) were inserted to study the influence of signal amplitude. Adding TMM reduced the spectrum signal amplitude to a more clinically relevant level and reduced Vmode to be close to the motor velocity (**Figure 3**). Doppler angle had a strong impact on Vmax due to ISB errors. Percentage increase in Vmax was in-dependent of the motor velocity (**Figure 4**). A study with a flow phantom (not shown here) also showed the similar amount of Vmax changes as θ varied, albeit without the knowledge of absolute errors.

Presenting author: Yi Zhang; Department of Radiology, Mayo Clinic, Rochester, Minnesota, USA.

Cite this article as:
Zhang Y, Lynch T, Hangiandreou NJ. Doppler string phantom for assessment of clinical doppler ultrasound velocity measurement. *Int J Cancer Ther Oncol* 2014; **2**(2):020246.
DOI: 10.14319/ijcto.0202.46

ISSN 2330-4049

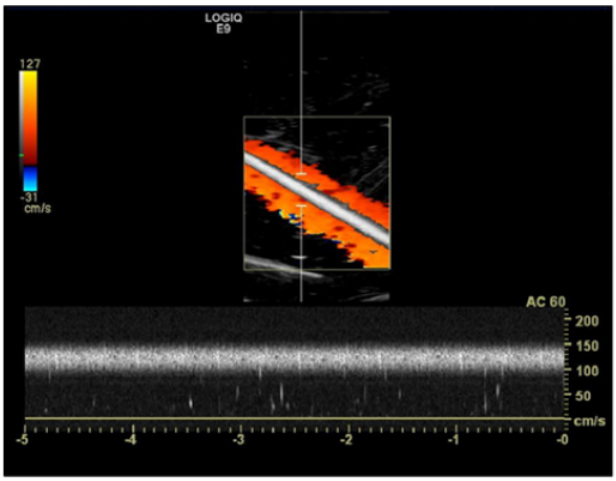

FIG.1: A representative Duplex US image of the Doppler String without TMM.

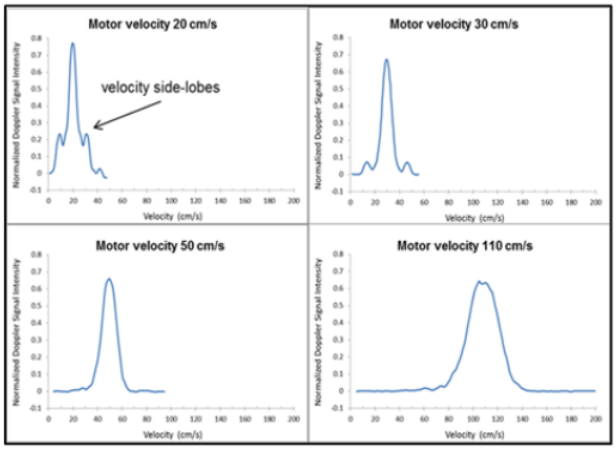

FIG.2: Representative mean spectrum profiles at different motor velocities. Velocities side-lobe artifacts appeared at low motor velocities.

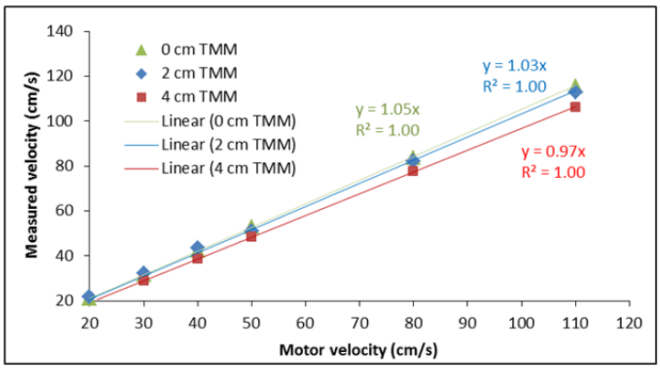

FIG. 3: Vmode against prescribed motor velocity with different Thicknesses of TMM.

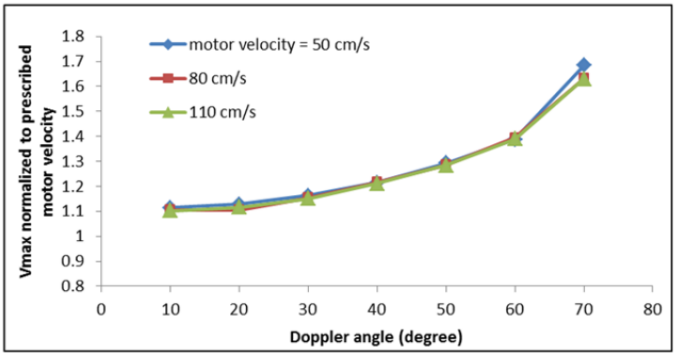

FIG.4: Vmax was normalized to the prescribed motor velocity and plotted against Doppler angle for three motor velocity stations (no TMM was inserted).

ISSN 2330-4049