Ultrasound in Med. & Biol., Vol. ■, No. ■, pp. 1–13, 2015

0301-5629/$ - see front matter

http://dx.doi.org/10.1016/j.ultrasmedbio.2015.10.024

● *Review Article*

BREAST LESIONS: QUANTITATIVE DIAGNOSIS USING ULTRASOUND SHEAR WAVE ELASTOGRAPHY—A SYSTEMATIC REVIEW AND META-ANALYSIS

Baoxian Liu, Yanling Zheng, Guangliang Huang, Manxia Lin, Quanyuan Shan, Ying Lu, Wenshuo Tian, and Xiaoyan Xie

Division of Interventional Ultrasound, Department of Medical Ultrasonics, Institute of Diagnostic and Interventional Ultrasound, First Affiliated Hospital of Sun Yat-Sen University, Sun Yat-Sen University, Guangzhou, China

(*Received* 3 *February* 2015; *revised* 27 *October* 2015; *in final form* 29 *October* 2015)

Abstract—The aim of this meta-analysis was to estimate the diagnostic performance of shear wave elastography (SWE) in differentiating malignant from benign breast lesions. A literature search of PubMed, Web of Science and Scopus up to November 2014 was conducted. A summary receiver operating characteristic curve was constructed, and pooled weighted estimates of sensitivity and specificity were calculated using a bivariate mixed-effects regression model. Thirty-three studies, which included a total of 5838 lesions (2093 malignant, 3745 benign) from 5397 patients, were finally analyzed. Summary sensitivity and specificity were 0.886 (95% confidence interval [CI], 0.858–0.909) and 0.866 (95% CI, 0.833–0.894), respectively. The pooled diagnostic odds ratio was 50.410 (95% CI, 34.972–72.664). And the area under the receiver operating characteristic curve of SWE was 0.94 (95% CI, 0.91–0.96). No publication bias existed among these studies (p = 0.245). In the subgroup analysis, sensitivity and specificity were 0.862 (95% CI, 0.811–0.901) and 0.875 (95% CI, 0.793–0.928) among 1552 lesions from 1429 patients in the 12 studies using acoustic radiation force impulse imaging and 0.897 (95% CI, 0.863–0.923) and 0.863 (95% CI, 0.831–0.889) among another 4436 lesions from 4097 patients in the 21 studies using supersonic shear imaging. When analysis confined to 9 studies evaluated the diagnostic performance of combination SWE and conventional ultrasound, the area under the curve was 0.96 (95% CI, 0.94–0.97), yielding a sensitivity of 0.971 (95% CI, 0.941–0.986) and specificity of 0.801 (95% CI, 0.733–0.856). SWE seems to be a good quantitative method for differentiating breast lesions, with promise for integration into routine imaging protocols. (E-mail: xxy1992@live.cn) **© 2015 World Federation for Ultrasound in Medicine & Biology.**

Key Words: **Shear wave elastography, Acoustic radiation force impulse imaging, Supersonic shear imaging, Breast lesions, Ultrasound, Meta-analysis.**

INTRODUCTION

Ultrasound (US) is widely used to distinguish malignant from benign breast lesions (Raza and Baum 1997). Compared with other early detection methodologies, US provides several advantages in breast cancer, including high spatial resolution, real-time imaging and low cost. The Breast Imaging Reporting and Data System (BI-RADS) for US has served as the standardized terminology for the assessment of breast lesions. Although US has high accuracy in the detection of breast lesions, it does not perform as well in differentiating malignant from benign lesions because its diagnostic specificity is relatively low.

With advances in US technology, strain elastography has emerged as a new imaging technique that can measure tissue stiffness as additional diagnostic information. In many commercial implementations, strain elastography presents tissue stiffness information in a color map superimposed on the real-time gray-scale ultrasound image. Previous studies have found that strain elastography is effective in the detection of breast cancer (Gong et al. 2011; Itoh et al. 2006). However, strain elastography can only qualitatively or semiquantitatively assess tissue stiffness.

Shear wave elastography (SWE) is a group of novel ultrasound-based elasticity technologies that allow the quantitative measurement of tissue stiffness. Instead of using external compression, commercially available US scanners are used to generate short-duration acoustic

Address correspondence to: Xiaoyan Xie, Department of Medical Ultrasonics, Institute of Diagnostic and Interventional Ultrasound, First Affiliated Hospital of Sun Yat-Sen University, Guangzhou-510080, China. E-mail: xxy1992@live.cn

Conflict of interest disclosure: The authors declare that they have no conflicts of interest.

Table 1. Characteristics of studies included

Study ID	Country	Study design	Standard reference	Inclusion year	No. of patients	Mean age (y)	No. of lesions available for analysis
Evans A, 2010	UK	N/A	Pathology/follow-up	N/A	52	53	53
Meng W, 2011	China	N/A	Pathology	Sep 2010–Dec 2010	86	45.6	76
Chang JM, 2011	Korea	Prospective	Pathology	Mar 2010–May 2010	158	48.1	182
Bai M, 2012	China	N/A	Pathology	Jan 2011–May 2011	108	44	143
Jin ZQ, 2012	China	Prospective	Pathology	Oct 2009–Aug 2011	95	43.5	122
Evans A, 2012	UK	Retrospective	Pathology	Apr 2010–Dec 2010	173	56	175
Berg WA, 2012	France	Prospective	Pathology/follow-up	Sep 2008–Sep 2010	939	52	939
Tozaki M, 2013	Japan	Retrospective	Pathology/follow-up	Mar 2012–May 2012	81	49	83
Wojcinski S, 2013	Germany	NA	Pathology/follow-up	May 2011–Dec 2011	129	55.9	145
Zhou J, 2013	China	Prospective	Pathology	Jul 2011–Sep 2011	173	45.3	175
Tamaki K, 2013	Japan	NA	Pathology	Oct 2011–Jul 2012	180	55	180
Ye L, 2013	China	NA	Pathology	Mar 2012–Dec 2012	75	42	86
Lee EJ, 2013a	Korea	Retrospective	Pathology	Jun 2012–Oct 2012	139	43.5	156
Lee SH, 2013b	Korea	Prospective	Pathology	Sep 2011–Nov 2011	134	49.1	134
Yoon JH, 2013a	Korea	Retrospective	Pathology	Jun 2012–Dec 2012	199	45.3	222
Yoon JH, 2013b	Korea	Retrospective	Pathology	Oct 2012–Jan 2013	236	45.1	267
Wang ZL, 2013	China	Prospective	Pathology	Mar 2010–Jun 2010	108	42.8	114
Chang JM, 2013	Korea	Prospective	Pathology	Feb 2010–Jun 2010	129	47.8	150
Youk JH, 2013a	Korea	Retrospective	Pathology	Jun 2011–Jan 2012	146	45.2	163
Youk JH, 2013b	Korea	Retrospective	Pathology	May 2011–Oct 2011	324	46	389
Gweon HM, 2013	Korea	Retrospective	Pathology	Jun 2011–Mar 2012	119	45.3	133
Xiao Y, 2013	China	NA	Pathology	N/A	82	43	106
Yao MH, 2014	China	NA	Pathology	Jul 2011–Dec 2012	146	43.2	206
Ianculescu V, 2014	France	Prospective	Pathology	Mar 2012–Jul 2012	110	N/A	110
Golatta M, 2014	Germany	Prospective	Pathology	May 2012–Aug 2012	103	51.0	104
Barr RG, 2014	USA	Prospective	Pathology	Mar 2011–Jun 2012	122	48.5	122
Youk JH, 2014	Korea	Retrospective	Pathology	Aug 2012–Sep 2012	123	46.7	130
Xiao Y, 2014	China	Retrospective	Pathology	Jun 2012–Nov 2012	93	40	125
Ko KH, 2014	Korea	Retrospective	Pathology	Jun 2012–Dec 2012	33	46.4	34
Olgun DÇ, 2014	Turkey	Prospective	Pathology	Jan 2012–Dec 2012	109	51	115
Lee SH, 2014	Korea	Retrospective	Pathology	Mar 2010–Feb 2012	159	45.6	159
		Prospective	Pathology	Apr 2012–Oct 2012	207	45.5	207
Klotz 2014	France	Retrospective	Pathology/follow-up	Jan 2012–Jun 2012	142	57.7	167
Kim MY, 2015	Korea	Retrospective	Pathology	May 2013–Oct 2013	164	45.3	166

SENS = sensitivity; SPEC = specificity; N/A = not applicable; AUC = area under receiver operating characteristic curve; ARFI = acoustic radiation force impulse; SSI = supersonic shear imaging; SWV = shear wave velocity; R-SWV = ratio of SWV; QM = quality measure; E_{max} = maximum elasticity; E_{mean} = mean elasticity value; E_{min} = minimum elasticity; E_{ratio} = ratio of elasticity values.

radiation forces that impart small (1–10 μm) localized tissue displacements, which are correlated with the local stiffness of the tissue. These displacements result in shear wave propagation and are tracked to calculate the shear wave velocity (SWV) or are converted to Young's moduli (Li et al. 2013; Meng et al. 2011). In 2014, three medical ultrasound companies were offering quantitative shear wave elastography products: Siemens acoustic radiation force impulse (ARFI) quantification, Supersonic Imagine supersonic shear imaging (SSI) and Philips ElastPQ. However, shear wave elastography for breast imaging was available only on Siemens' and Supersonic Imagine's systems. In ARFI imaging, a sequence of rapid bursts of focused ultrasound pulses is generated to create a localized displacement of a few microns, which generates transient shear wave propagation with cylindrical symmetry away from the pushing-beam's axis. The shear displacement is along the ultrasound imaging beam, allowing the use of correlation tracking or Doppler to measure the small displacements of the shear wave and detect the time it arrives at lateral positions (Bamber et al. 2013). In SSI, the acoustic radiation force focus is swept down the acoustic axis faster than the shear wave speed to generate tissue displacements at all positions along the acoustic axis almost simultaneously. This procedure induces a shear wave that spreads less and thus decays less rapidly with distance than does a single pushing focus in ARFI. Plane wave transmission for shear wave tracking improves the frame rate of shear wave up to 20 Hz. The high frame rate allows the shear waves to be followed in real time in two dimensions, and the time of arrival is detected to create images of shear wave speed or converted to images of Young's moduli (Bamber et al. 2013).

Several studies with relatively small patient populations have obtained promising results for SWE in the differentiation of breast lesions. Although Li et al. (2013) performed a meta-analysis to summarize the diagnostic performance of SWE in the differentiation of breast lesions, only nine studies were searched and analyzed.