Correlation of electric conductivity with prognostic factors in invasive breast cancer

Soo-Yeon Kim[1], Jaewook Shin[2], Dong-Hyun Kim[2], Min-Jung Kim[1], and Eun-Kyung Kim[1]

[1]*Radiology, Severance Hospital, Yonsei University College of Medicine, Seoul, Seodaemun-gu, Korea,* [2]*Electronic and Electronic Engineering, Yonsei University, Seoul, Seodaemun-gu, Korea*

Background and Purpose

Electric tissue properties can be described by conductivity and they are expected to be a possible candidate for quantitative diagnostic parameter [1]. Electric properties tomography (EPT) has been developed to determine the electric conductivity using the radiofrequency transmit field map of a standard MR scan [1]. The electric conductivity has shown its potential to differentiate benign and malignant breast tissue in vivo using EPT [2]. Traditional pathologic factors such as histologic type, tumor size, axillary lymph node (ALN) metastasis, lymphovascular invasion (LVI), histologic grade in conjunction with hormone receptor (Estrogen receptor (ER), Progresterone receptor (PR)), HER-2, and Ki-67 status are the known prognostic factors in invasive breast cancer [3]. The correlation between the electric conductivity and those markers will provide noninvasively helpful information for predicting the prognosis and treatment response in patients with invasive breast cancer. Therefore, the aim of this study was to investigate the correlation between the electric conductivity with prognostic factors of invasive breast cancer.

Materials and Methods

We retrospectively evaluated the electric conductivity of 13 invasive breast cancers greater than 1cm in size using the EPT reconstruction algorithm [1] and multi-receive coil combined technique [4]. Those were imaged on a 3T system (MR750, GE Healthcare, Waukesha, WI) with a 8-channel breast coil using 2D T2-weighted fast spin echo (FSE) sequence (TR/TE_{eff}=4420/102ms,voxel size=0.81×1.3×3mm^3). Pathologic and molecular markers including histologic type, tumor size, ALN metastasis, LVI, histologic grade, ER, PR, HER-2, and Ki-67 were evaluated on surgical specimen. 13 invasive breast cancers were separated into two dichotomized groups based on each marker, and the difference between the mean values of the two groups was tested using the Mann-Whitney test.

Results

Figure 1 demonstrates the box-and-whisker plots of mean conductivity in two dichotomized groups based on each prognostic marker. The mean conductivity was higher in invasive ductal carcinomas (IDC) than in other specific types of invasive breast carcinoma (Fig.1a). Smaller tumors (<2cm) had higher conductivity than larger tumors greater than 2cm (Fig.1b). The conductivity values identified in breast cancers with high histologic grade were higher than those with low histologic grade (Fig.1e and Fig.2-3). Breast cancers with ALN metastasis or LVI showed higher conductivity than those without (Fig.1c-d). Figure 4-5 demonstrate that the IDC with ALN and LVI (+) (Fig.4) shows higher conductivity than non-IDC with ALN and LVI (-) (Fig.5). However, statistical analysis did not show significant differences in all groups (p-value>0.05), partly due to small sample size.

Discussion

In this study, the electric conductivity can be different according to the histologic type of invasive breast cancer. Higher conductivity was observed in IDCs than in three other specific types (mixed tubular and invasive cribriform, mucinous, and invasive micropapillary) of invasive breast cancer. We hypothesized that the larger tumors have higher conductivity than smaller ones due to internal necrosis, based on the finding of the study by D Haemmerich et al [5]. But contrary to our expectation, conductivity in smaller tumors of 1-2cm was higher than that in larger tumors greater than 2cm. But, the sample size was small, and there was much difference in size between group of 1-2cm (n=4, mean, 1.6cm; range, 1.6-1.9cm) and >2cm (n=9, mean, 2.5cm; range, 2.1-3.3cm). In this study, we observed that higher conductivity values were identified in breast cancers with the established predictors of poor prognosis (ALN metastasis, LVI and high histologic grade) [3]. The presence of LVI in the peritumoral tissue might affect the electric conductivity by changing the ionic concentration gradients between intra- and extra-tumoral compartments [6]. Histologic grade is composed of tubule formation, nuclear grade, and mitotic rate [3]. Increased conductivity in tumors with high histologic grade (high mitotic rate) compared to those with low histologic grade might be explained by the depolization of tumor cells with high mitotic rate [7].

Conclusion

Our results show the possibility that the electric conductivity can be differentiated according to the known prognostic markers in invasive breast cancers. Further studies are needed about this issue with the larger sample size.

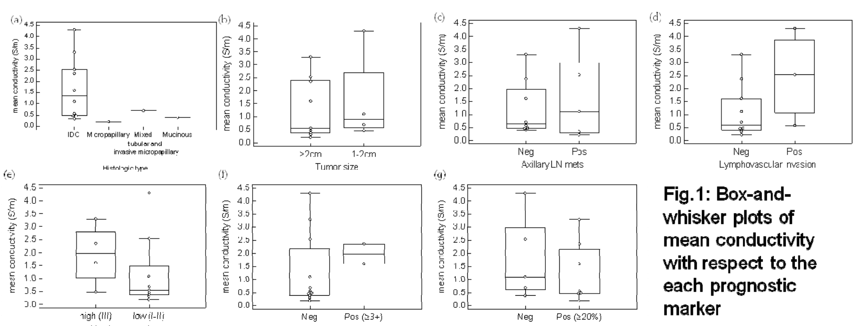

Fig.1: Box-and-whisker plots of mean conductivity with respect to the each prognostic marker

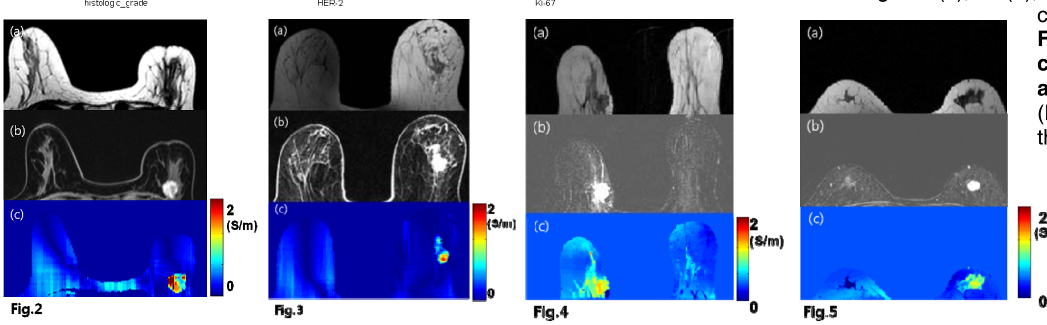

Fig. 2-5: Four examples of invasive breast cancers with different conductivity according to the prognostic factors.
(a) FSE (b) subtracted contrast-enhanced image and (c) conductivity map. Mean conductivity of the tumor was measured on conductivity map.

Fig 2. **IDC with high (III) histologic grade** (1.8cm, ALN(-), LVI(-), ER(+), PR(+), Her-2(-), Ki-67(-)) and the mean conductivity of 1.19±0.78 S/m.

Fig 3. **IDC with low (II) histologic grade** (2.2cm, ALN(-), LVI(-), ER(-), PR(-), Her-2(-), Ki-67(-)) and the mean conductivity of 0.85±0.42 S/m.

Fig.4. **IDC with ALN and LVI (+)** (1.9cm, Low histologic grade (II), ER(+), PR(+), HER-2(-), Ki-67(-)) and the mean conductivity of 1.03±0.16 S/m.

Fig.5. **Mixed tubular (50%) and invasive cribriform (50%) carcinoma with ALN and LVI (-)** (1.6cm, Low histologic grade (I), ER(+), PR(+), Her-2(-), Ki-67(-)) and the mean conductivity of 0.72±0.32 S/m.

Reference

[1] Voigt T et al., MRM 2011;66;456-466 [2] Katscher U et al., ISMRM 21 (2013) 3372 [3] Stuart J.Schnitt & Laura C.Collins (2012) Biopsy interpretation of the breast: LMW [4] J Shin et al., ISMRM (2013) 4180 [5] D Haemmerich et al., Physiological Measurement 2003; 24; 251-260 [6] Offner FF, IEEE Trans Biomed Eng 1984;31;863-868 [7] Andrew A. Marino et al. Tumor Biol 1994;15;82-89