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超声弹性成像技术在乳腺病变中的临床应用进展

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摘　要

我国乳腺癌发病人数及死亡人数均居世界首位，早发现、早诊治对乳腺癌患者至关重要。超声弹性成像技术(Ultrasonic Elastography, UE)可以提高常规超声诊断乳腺癌的准确性，UE技术主要分为应变式弹性成像技术、声辐射脉冲成像技术和剪切波弹性成像技术三大类，UE技术不只在乳腺病变良恶性的鉴别方面，还在乳腺影像报告和数据系统(Breast Imaging Reporting and Data System, BI-RADS)分类优化、新辅助化疗疗效和乳腺癌患者预后评估等方面发挥着重要作用。

关键词

乳腺，超声弹性成像，应用进展

Progress in Clinical Application of Ultrasound Elastography Technology in Breast Lesions

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Abstract

The number of breast cancer cases and deaths in China ranks first in the world. Early diagnosis and treatment are crucial for breast cancer patients. Ultrasound elastography (UE) can help improve the accuracy of conventional ultrasound in the diagnosis of breast cancer, UE is mainly di-

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vided into three categories: Strain Elastography, Acoustic Radiation Force Imaging and Shear Wave Elasticity, which can not only play an important role in the differentiation of benign and malignant breast lesions, but also plays an important role in optimizing the BI-RADS classification, the efficacy of neoadjuvant chemotherapy and the prognosis evaluation of breast cancer patients.

Keywords

Breast, Ultrasound Elastography, Application Progress

1. 引言

乳腺病变已成为长期困扰女性健康的问题之一，其中乳腺癌已超过肺癌，成为女性恶性肿瘤之首，且发病率持续升高，是世界第二大常见癌症，也是癌症死亡的第五大原因[1] [2]。临床发现尽早检出乳腺癌，并及时治疗，能够降低死亡率，提高生存率。目前，乳腺影像学检查方法常用的有钼靶、CT、核磁共振、超声等。中国抗癌协会乳腺癌诊治指南与规范(2024 年版) [3]指出乳腺 X 线筛查提示致密型乳腺(c 型或 d 型)，推荐超声检查作为乳腺 X 线筛查的有效补充，说明 US 在致密性乳腺检查中的优势，我国女性乳房体积普遍小且密度普遍高，加之超声与 CT、核磁共振相比，更加实惠、无辐射、能实时显像等，故在乳腺癌早期筛查、诊断与治疗中超声发挥着重要作用，超声也成为我国临床医师和患者选择的重要影像学检查方法[4]。乳腺影像报告和数据系统(Breast Imaging Reporting and Data System, BI-RADS)对乳腺超声检查制定了规范化的诊断报告，有很大的临床实践指导意义，但是 BI-RADS 报告系统仅提供了不同类别乳腺病变的恶性概率以及相应的临床处理建议，并未给出具体的诊断标准评分[5]，如何更加准确判断乳腺病变的良恶性显得尤为重要。超声弹性成像技术(Ultrasonic Elastography, UE)作为新的超声成像模式，在常规超声形态学检查的基础上，无创性增加了组织硬度的检测，提高了乳腺病变的诊断准确率。在这篇综述中，我们将介绍这三种超声弹性成像技术在乳腺病变诊断中的应用进展。

2. 乳腺弹性成像技术的相关原理

1991 年 Ophir 等人[6]第一次提出弹性成像的概念，之后随着医疗科技迅速发展，超声诊断仪器商家将弹性成像技术引入仪器中，运用于疾病的辅助诊断，其原理是给予组织一个力量(静态或者动态的)，组织就会产生响应的变化，如速度、位移的改变，通过相应的软件将给力前后的变化通过彩色编码或者灰阶成像显示，定性或定量提供组织另一基本属性(弹性硬度)。结合弹性成像技术比单纯二维常规超声对病变的良恶性鉴别能提更多的诊断价值[7]，进而提高诊断准确性。乳腺由乳腺腺体、脂肪组织、纤维组织等不同组织构成，1998 年，Krouskop 等[8]研究表明乳腺组织内不同的组织有不同的弹性系数，浸润性导管癌弹性系数最大，其次是非浸润性导管癌，脂肪组织最小，此研究成果为超声弹性成像技术在诊断乳腺疾病中提供了一定的依据，且乳腺位置表浅、易受外力影响发生形变，又无自主运动干扰，故弹性成像技术在乳腺病变诊断中有很强的实用性，乳腺也是目前弹性技术运用得最早、最成熟的器官。

3. 超声弹性成像技术的分类和应用

弹性成像是过去二十几年来发展起来的一种新的技术，自从超声诊断仪器中增添了弹性成像技术，

超声医师开始在乳腺等器官上尝试应用弹性成像技术，近年来广泛应用于肝脏[9]、前列腺[10]等器官。根据其产生作用力的原理不同大致可分为三种：应变式弹性成像技术、声辐射脉冲成像技术和剪切波弹性成像技术，大量学者以不同的方法评估乳腺病变的良恶性，现已被证明在乳腺病变良恶性评估方面具有较高的准确性[11]。

3.1. 应变式弹性成像(Strain Elastography, SE)

SE 作为第一代弹性成像技术，是通过操作者手动施压或利用被检者的呼吸、心血管脉动完成，前者仅对浅表器官如乳腺等适用，深部组织扫查不满意，后者对深部组织较前者有一定的优势[12]，然后通过数字转换器、显示器等形成弹性图。观察者根据弹性图中不同颜色的占比和分布来判断感兴趣区的软硬程度。弹性评分法(5 分法)最早由日本学者 Itoh [13]提出，我国学者罗葆明等[14]人提出了 7 分法，认为较 5 分法更加准确，目前我国乳腺弹性评分法大多采用罗葆明等[15]提出的改良 5 分法，改良 5 分法评分标准：1 分：病灶全部或绝大部分显示为绿色；2 分：病灶中央呈蓝色，周边为绿色；3 分：病灶范围内绿色和蓝色所占比例相近；4 分：病灶整体为蓝色或内部伴有少许绿色；5 分：病灶及周边组织均皆为蓝色，内部伴或不伴有绿色。不同颜色代表不同软硬程度，因超声仪器厂家不同，设置也不同。与传统 5 分法相比，改良分法诊断准确性更高[16]。

3.2. 声辐射脉冲成像技术(Acoustic Radiation Force Impulse, ARFI)

ARFI 技术是通过超声探头给组织实施局部高强度辐射力，触发组织产生一系列的形变、位移等，之后终止声辐射力，组织恢复原状的过程中仪器能收到不同时间点的形变或位移情况，从而反映组织的软、硬情况。相比于应变力弹性成像，声辐射力脉冲成像技术无需人工施压，避免了操作者的主、客观影响。ARFI 技术又分为声触诊组织成像(Virtual Touch Tissue Imaging, VTI)技术和声触诊组织定量(Virtual Touch Tissue Quantification, VTQ)技术。VTI 属于定性诊断技术，通过检测感兴趣区组织的纵向位移的变化，运用不同的灰度或颜色反映感兴趣区组织的软硬度，通常用黑、白、灰显示组织的软、硬度[17]，灰阶图像上越黑代表组织硬度越硬，反之越白表示所检部位越软[18]。VTI 技术和 SE 技术均会因操作者人为视觉的主观因素或操作力度不均客观因素造成结果的准确性及可重复性差，为减少对操作者的依赖性，国内外学者尝试引用弹性应变率比值法、面积比及长度比[19] [20] [21]，来减少操作者的主观影响，前者比较病变与其相邻的腺体组织或脂肪组织的弹性杨氏模量值比或速度比[22] [23]，后两者是弹性图中病变的大小和对应常规二维图中病变大小的比值[24]，均属于半定量评价指标，大量文献[25] [26] [27] [28] [29]表明比值法对乳腺病变良恶性鉴别诊断是有价值的；VTQ 技术是一种定量的检查方法，通过检测感兴趣区组织的剪切波速度值(Shear Wave Velocity, SWV)来判断组织的软硬程度，剪切波属于横向波，量纲单位为“m/s”，剪切波速度值(SWV)越高，则所测组织越硬、弹性越差[30] [31]，反之则代表组织越软。VTQ 技术改善了 SE、VTI 弹性成像技术仅能定性或半定量评估的局限性[32] [33]。总之 ARFI 技术自发辐射力给被检部位，避免了手动加压及被检者的自主运动，降低了对操作者的依赖，具有重复性好、操作简单等优势，但 ARFI 亦有不足之处，VTI 无法实时成像，VTQ 测量取样框大小无法调节，SWE 速度测量范围较窄，所测速度超过 9 m/s，则无法显示具体数值，显示器仅显示“X.XX”。

3.3. 剪切波弹性成像(Shear Wave Elasticity, SWE)

SWE 技术分为点式剪切波弹性成像(Point Shear Wave Elastography, pSWE)和二维剪切波弹性成像，其中 pSWE 一般就指的是以上所述的 ARFI 中的 VTQ 技术[34]；二维剪切波弹性成像是目前最新的弹性成像技术，就是目前大家熟知的 SWE 技术，由探头自身发射脉冲激励给组织器官，产生的“马赫锥”反应，产生横向剪切波，超声仪器内高速成像技术进行彩色编码并获取弹性图像[35]，通过计算不同方位上

剪切波通过的时间，计算出剪切波速度，再依据公式 $E = 3\rho C2$，(E 为杨氏模量值，C 为剪切波传播速度，ρ 为组织密度)计算出杨氏模量值。剪切波速度越高、E 值越大，代表组织越硬，显示为红色；反之剪切波速度越低，E 值越小，组织越软，表现为蓝色：介于两者的 E 值显示为绿色。SWE 的定量测量指标有弹性最大值(Emax)、弹性平均值(Emean)、弹性比值(Eratio)、弹性标准差(Esd)，剪切波传播最大速度(SWVmax)、剪切波传播平均速度(SWVmean)等。国内外研究表明：鉴别诊断乳腺良恶性病变所采用的 SWE 参数及临界值不一致[36] [37]，Berg 等(2012)采用 SWVmean、SWVmax、SWVmin、弹性应变率比值法、面积比及直径比等联合评估乳腺病变良恶性，得到的最佳截断值(Emax = 80 kPa)，而 Tozaki M 等(2011)视觉模式与杨氏模量值联合鉴别乳腺病变良恶性，在模式 4 中，良性病变(50 kPa)低于恶性病变(61 kPa)，但有些国外多中心临床研究的截断值(Emax = 80 kPa) [36]与我国公布多中心临床研究最佳值相接近(Emax = 60 kPa) [38]。SWE 也会因感兴趣区液化、间质原变性、钙化等导致低于或高于截断值[39]，一般来说深度小于 3 mm 病变也不适合使用 SWE [35]，也需要被检者良好的配合，才能获得更准确的 SWE 测值，但大量文献证明[37] [40] SWE 均能提高乳腺病变良恶性的评估。剪切波超声弹性成像技术较前两者具有更好的客观性、可重复性、操作者依赖性小等优点，临床应用较为广泛[41] [42]。

综上所述，超声弹性成像技术作为非侵入性的无创技术，已广泛应用于乳腺病变良恶性的诊断，并在预测乳腺癌腋窝淋巴结转移与否、弹性成像与乳腺病变不同病理类型相关性研究、乳腺癌新辅助化疗的评估、乳腺 BI-RADS 分类的优化方面[43] [44] [45] [46] [47]也发挥这重要作用，尽管超声弹性成像技术受多种因素的影响，如操作者用力大小、视觉感知差别、病变自身成分的复杂性及良恶性病变重叠等，都会对结果的准确性产生一定的影响，但是超声弹性成像在一定程度上可以弥补常规二维超声无法显示组织硬度的缺点，增加了新的诊断见解和诊断思路，随着医学技术的不断发展，超声弹性成像技术将在临床工作中发挥更加重要作用。

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