# Chapter 1
# Robustness Studies of Ultrasound CADx in Breast Cancer Diagnosis

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## 1. ABSTRACT

*This chapter will focus on the robustness, or reliability, of computer-aided diagnosis, abbreviated as CADx. In CADx, computerized analysis is used to characterize abnormalities identified by a human user (e.g., a radiologist). CADx is part of the broader area of quantitative imaging (Giger, Chan, & Boone, 2008). Other examples of quantitative imaging applications include computer-aided detection (Drukker, et al., 2002; Drukker, Giger, & Mendelson, 2003), computer-aided prognosis (Bhooshan, et al., 2010), and computer-aided assessment of response to therapy (Shi, et al., 2009; Shiraishi, Li, Appelbaum, Pu, & Doi, 2007). The task of primary interest in this chapter is the diagnosis of breast cancer using sonographic images(i.e., the distinction between benign and malignant breast lesions). The only steps that require human interaction are the identification of suspicious abnormalities prior to the computerized analysis by the CADx system and the interpretation of the CADx results. It is important to note that CADx only provides the radiologist with additional information. The final decision as to whether or not a given abnormality is worrisome lies with the radiologist. In order for CADx to be of potential help it is required that a CADx system demonstrates not only good but also consistent performance. The latter aspect is the focus of this chapter in which the authors will explore causes of variability and investigate CADx performance under different realistic scenarios.*

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## 2. CADX FOR BREAST ULTRASOUND

### 2.a. Overview

To date, breast ultrasound largely functions as a diagnostic – rather than a screening – method and is used to improve specificity in the assessment of abnormalities seen on mammography or of palpable masses found during clinical breast exams. Patients with a suspicious abnormality seen on mammography frequently undergo a subsequent breast ultrasound exam to avoid unnecessary biopsies. Ultrasound is also frequently used along with mammography and breast MRI in screening protocols for patients at high risk of developing breast cancer. The rather recent advent of multi-modality imaging approaches in clinical practice, as well as improved technology, has substantially improved diagnostic accuracy. However, the positive predictive value of lesion biopsy in finding cancer could still be substantially improved and we believe that computerized analysis has the potential to help radiologists make correct diagnoses.

The application of CAD to breast ultrasound has been under investigation for a relatively short period of time, but the fundamental designs of these systems are similar to previous systems developed for other modalities like mammography (see Figure **1**). There are currently a number of methods being developed for the automated detection of sonographic lesions (Drukker, et al., 2002; Drukker, et al., 2003; Mogatadakala, Donohue, Piccoli, & Forsberg, 2006; Yap, Edirisinghe, & Bez, 2008) as well as for the automatic classification of lesions (Chen, et al., 2003; Chen, Chang, Kuo, Chen, & Huang, 2002; Cheng, et al., 2010; Cui, et al., 2009; Drukker, Giger, Vyborny, & Mendelson, 2004; Gefen, et al., 2003; Giger, et al., 1999; Horsch, Giger, Huo, Vyborny, & Venta, 2001; Horsch, Giger, Venta, & Vyborny, 2001; Horsch, Giger, Venta, & Vyborny, 2002; Huang, et al., 2008; Joo, Yang, Moon, & Kim, 2004; Lee, et al., 2009; Moon, et al., 2010; Moon, et al., 2010; Sahiner, et al., 2004; Wu & Moon, 2008). These systems make use of a variety of visual queues and characteristics that are often utilized by radiologists, as well as other non-visual characteristics like wavelet-based features or echogenic texture, to detect, segment and/or characterize sonographic lesions. The lesions are then classified as "benign" or "malignant" using a variety of different automated classification methods, such as neural networks or discriminant analysis. Commercial systems currently on the market that are advertised as "breast ultrasound CAD" are not computer-aided detection and/or diagnosis as traditionally defined; they only provide the user with computerized lesion descriptions. This includes systems like the BreastScore/Image Companion system (Almen Laboratories Inc, Vista, CA) and the B-CAD system (Medipattern Co, Toronto, Canada), which are marketed (somewhat incorrectly) as computer-aided diagnosis systems. While research has been done on CAD for breast ultrasound in laboratory settings, there are currently no breast ultrasound CAD systems commercially available for use in a clinical environment.

### 2.b. Performance Metrics

Before addressing the issue of robustness (i.e., consistent performance of CADx under different circumstances), we will briefly introduce accepted methods for performance assessment. We will focus on the stand-alone performance of a CADx scheme, not on the effect CADx may or may not have on the performance of a radiologist in his or her clinical assessment of a patient.

The task of interest – the distinction between benign and malignant breast lesions – is a typical 2-class classification task and as such its performance is generally analyzed using Receiver Operator Characteristic (ROC) Analysis (Metz, 1978). The latter may be done using parametric (Metz & Pan, 1999; Pesce & Metz, 2007) or non-parametric (Yousef, Wagner, & Loew, 2004)

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