ImageChecker
Computer-Aided Detection

Understanding ImageChecker® 3D Calc CAD 1.1

MAN-08078-002 Rev 001

HOLOGIC®

Technical Support

If any issues arise or you have any questions, contact Hologic Technical Support at:

United States Technical Support:

Tel: +1.800.760.8342

Email: imgsupport@hologic.com

European Technical Support:

Tel: +32 2 711 45 45

Email: BE-Techsupport@hologic.com

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Hologic, Inc.
36 Apple Ridge Road
Danbury, CT, 06810 USA
Tel: 1.800.447.1856

EC REP **Hologic BV**
Da Vincilaan 5
1930 Zaventem
Belgium
Tel: +32 2 711 46 80
Fax: +32 2 725 20 87

For more information about Hologic products, services, and facilities, visit **www.hologic.com**.

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Chapter 1: Introduction

ImageChecker® 3D Calc CAD is a software application used for analyzing Breast Tomosynthesis (BT) datasets. The software is a licensed option with Hologic's Cenova™ T-Series server or any server with comparable functionality (that meets the ImageChecker 3D Calc CAD data input and output requirements).

The information in this manual is intended to serve as a reference for radiologists and clinic personnel who need to understand how computer-aided detection (CAD) can be integrated into their practices.

1.1. Intended Use

ImageChecker 3D Calc CAD is a software application intended to identify and mark regions of interest on breast tomosynthesis images to bring them to the attention of the radiologist after the initial reading has been completed. ImageChecker 3D Calc CAD assists the radiologist in minimizing observational oversights by identifying areas on the tomosynthesis images that may warrant a second review. This software version is designed to detect clusters of microcalcifications. It does not detect mass lesions. ImageChecker 3D Calc CAD runs on a Windows platform.

1.2. Intended User

ImageChecker 3D Calc CAD is intended to be used by physicians or radiation technologists working in a hospital, outpatient clinic, or a breast imaging center.

1.3. Patient Target Group

The device is intended to be used in the population of patients undergoing screening mammography.

1.4. Contraindications

There are no known contraindications.

1.5. Using This Manual

This manual is organized as follows:

- **Chapter 1: Introduction** provides an overview of the ImageChecker 3D Calc CAD application including features, benefits, and precautions for use.
- **Chapter 2: Image Processing and Supported Views** explains how information flows through systems with ImageChecker 3D Calc CAD, the supported views, and how to manage workflow.
- **Chapter 3: Algorithm Description** describes how the ImageChecker 3D Calc CAD algorithm analyzes breast tomosynthesis datasets.

This manual uses the following conventions to provide technical and safety information of special interest.

⚠ ***WARNING!*** *An instruction that, if not followed, can result in a hazardous condition.*

⚠ ***CAUTION:*** *An instruction that, if not followed, can result in damage to the system.*

Important: *An instruction provided to ensure correct results and optimal performance, or to clarify limitations of the device.*

Note: *Information provided to clarify a particular step or procedure.*

1.6. Resources Available

In addition to this manual, the following resources are available to assist you.

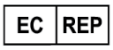
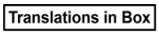
- **Training:** The Hologic Applications team is available to train your staff, should you feel they need additional training. To purchase additional personalized instruction, contact your Hologic Account Manager.
- **Website:** The Hologic website (www.hologic.com) provides quick access to electronic versions of User Guides. You can also obtain additional copies of printed User Guides through your Hologic Account Manager or through the Hologic Technical Assistance Center (1-866-243-2533).

1.7. Product Complaints

Report any complaints or problems in the quality, reliability, safety, or performance of this product to Hologic. If the device has caused or added to patient injury, immediately report the incident to Hologic Authorized Representative and Competent authority of the respective member state or country.

The Competent Authorities, for medical devices, are usually the individual Member States' Ministry of Health, or an agency within the Ministry of Health.

1.8. Symbols

Symbol	Description	Standard
	Prescription use only	FDA 21 CFR 801.109
	Warning	ISO 7010, Reference W001
	Caution	ISO 15223-1, Reference 5.4.4
	Note	Hologic
	Manufacturer	ISO 15223-1, Reference 5.1.1
	Authorized representative in the European Community	ISO 15223-1, Reference 5.1.2
	Consult Instructions for Use	ISO 15223-1, Reference 5.4.3
	Catalog number	ISO 15223-1, Reference 5.1.6
	Revision	Hologic
	Country of Manufacture	ISO 15223-1, Reference 5.1.11
	Date of manufacture	ISO 15223-1, Reference 5.1.3
	Medical Device	ISO 15223-1, Reference 5.7.7
	CE Mark European Conformity	MDR Regulation (EU) 2017/745
	Serial Number	ISO 15223-1, Reference 5.1.7
	Patents	Hologic
	Translations in Box	Hologic

1.9. Warnings and Precautions

Note: *For warnings and precautions related to the installation, operation, and maintenance of the Cenova server, refer to the Cenova User Manual.*

Important: *Please note the following:*

- *The radiologist should base interpretation only on diagnostic-quality images. Do not depend upon ImageChecker 3D Calc CAD marks for interpretation.*
- *The software is a detection aid, not an interpretative aid. Review ImageChecker 3D Calc CAD results only after the first reading of the tomosynthesis images.*
- *The software does not enhance the tomosynthesis images; rather it identifies regions on tomosynthesis images that should be re-examined.*
- *The software identifies the locations of calcification clusters, which are then highlighted on the displayed image. These clusters may not represent cancer, and the skill of the user is still required for proper interpretation of the marked areas.*
- *ImageChecker 3D Calc CAD software does not identify all areas that are suspicious for cancer.*
  - *The software does not identify all clusters and a user should not be dissuaded from working up a cluster if the software fails to mark that site.*
  - *The software is not designed to detect changes from prior examinations.*
  - *Conditions of the breast that diminish mammographic sensitivity, such as density of normal tissue, may diminish the sensitivity of the software.*
  - *The algorithm sensitivity depends on the site-specific operating point chosen. For more information, see* ***3.4. Operating Points****.*
- *ImageChecker 3D Calc CAD does not process images that include the following DICOM view modifiers (with SNOMED* codes):*
  - *Cleavage (R-102D2)*
  - *Magnification (R-102D6)*
  - *Spot Compression (R-102D7)*

  **SNOMED = Systematized Nomenclature of Medicine.*
- *The performance of the software has not been characterized for tomosynthesis studies from patients with:*
  - *Breast implants. For patients with implants, process only implant-displaced views.*
  - *Partial views (e.g., 'mosaic' views) without a complete breast border. Process only views with complete breast borders.*

1.10. Overview of ImageChecker 3D Calc CAD

The ImageChecker 3D Calc CAD software:

- Analyzes breast tomosynthesis datasets produced by the Selenia Dimensions system.
- Identifies regions of interest that include clusters of bright spots (suggestive of calcification clusters).
- Generates results that includes CAD marks and related data identifying and characterizing the regions of interest.

The server sends the results to a Hologic SecurView review workstation where the results appear with the tomosynthesis reconstructed slices produced by Selenia Dimensions.

The ImageChecker 3D Calc CAD algorithm marks visually perceptible structures that have some of the generally accepted characteristics of calcifications. The marked areas may be something other than an actual abnormality, which is generally recognized by the radiologist upon a second review of the reconstructed slices. After making an initial interpretation from the diagnostic-quality reconstructed slices, the radiologist displays the ImageChecker 3D Calc CAD results and decides whether to reinspect the marked regions on the reconstructed slices.

Result Formats

There are two types of ImageChecker 3D Calc CAD marks:

- **RightOn** identifies regions of interest suggestive of calcifications by placing a triangle over each suspected calcification cluster.
- **Citra 3D** includes two display options: (1) the CAD marks can appear as dotted outlines around the suspected calcification cluster, and (2) the PeerView™ 3D license feature outlines individual calcifications within the dotted outline. When viewed at the workstation, the results help radiologists understand better why a region of interest received a CAD mark.

For additional information on result formats, see **Chapter 3: Algorithm Description**.

Operating Points

ImageChecker 3D Calc CAD offers three operating points (i.e., CAD algorithm thresholds) to accommodate site preferences: operating point 0, which emphasizes specificity (a low false-mark rate), operating point 1, which is a balanced intermediate point, and operating point 2, which emphasizes sensitivity.

When your system is installed, the server software is configured to use operating point 2 by default, although you can choose another setting if you prefer. At any time your service representative can change the operating point. For new customers, Hologic recommends using the default setting for the first four to six weeks to allow users to become familiar with the ImageChecker marks and algorithm behavior. For more information, see **3.4. Operating Points**.

1.11. Benefits of ImageChecker 3D Calc CAD

Normal breast tissue varies widely among women, even for the same woman over time. The radiologist must balance the need for accurate cancer detection with the need to limit the number of unnecessary work-up procedures. The combination of viewing a large number of cases, radiologist fatigue, the complex image of the breast structure, and the methodical search for observable characteristics of breast disease can result in false-negative readings. In fact, studies show that many breast cancers are visible and actionable in retrospect.[1,2,3]

Unlike traditional mammography, tomosynthesis can separate overlying tissue structures that otherwise would obscure lesions. However, calcification clusters can be overlooked due to the large number of reconstructed slices in a tomosynthesis study, and the fact that a calcification cluster may lie across many slices.

ImageChecker 3D Calc CAD functions like a spellchecker for tomosynthesis studies. It is designed to help radiologists reduce the number of false-negative readings due to observational oversight.

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1 Birdwell RL, Ikeda DM, O'Shaughnessy KF, Sickles EA. Mammographic characteristics of 115 missed cancers later detected with screening mammography and the potential utility of computer-aided detection. *Radiology 2001*; 219: 192-202.

2 Hofvind S, Skaane P, Vitak B, Wang H, Thoresen S, Eriksen L, et al. Influence of design on percentages of missed interval breast cancers: Retrospective study of interval cancers in a population-based screening program. *Radiology 2005*; 237: 437-443.

3 Duijm LEM, Groenewoud JH, Hendriks JHCL, de Koning HJ. Independent double reading of screening mammograms in the Netherlands: Effect of arbitration following reader disagreements. *Radiology 2004*; 231: 564-570.

Chapter 2: Image Processing and Supported Views

This chapter explains how information flows through systems with ImageChecker 3D Calc CAD, the supported views, and how to manage workflow.

2.1. Image Processing

The ImageChecker 3D Calc CAD software is provided on a server that manages DICOM images and processes the algorithm results. Image and data flows are generally as follows:

1. A Selenia Dimensions system produces tomosynthesis datasets in two forms:
   - For Processing (Raw) Projection images
   - Reconstructed slices
2. The Selenia Dimensions system sends the Raw Projection images to the server software and sends the reconstructed slices to a Hologic workstation.
3. The server software receives the Raw Projection images, groups them by the identified study, and passes the studies to the ImageChecker 3D Calc CAD software.
4. ImageChecker 3D Calc CAD analyzes the images and studies, produces results for each study in the form of an .xml file, and outputs the file to the server software.
5. The server software generates results in the form of a proprietary DICOM Secondary Capture Image object.
6. For each study, the review workstation displays the ImageChecker 3D Calc CAD results with the reconstructed slices produced by the Selenia Dimensions system. Radiologists can review the ImageChecker 3D Calc CAD results at any time as a normal part of the reading process.

   Note: *Display of ImageChecker 3D Calc CAD results requires a specialized workstation such as Hologic SecurView 7.2 or later. The appearance of images on the workstation depends upon the acquisition device and the workstation's display capabilities, and is not influenced by the ImageChecker 3D Calc CAD software.*

   Note: *The appearance of the images on the workstation is dependent upon the acquisition modality and the workstation's display capabilities, and is not affected by the ImageChecker 3D Calc CAD software.*

   At the review workstation, the radiologist begins by examining the reconstructed slices. After making an initial interpretation, the radiologist displays the ImageChecker 3D Calc CAD results. The radiologist can then switch off the CAD results, reinspect the marked areas, and form a diagnosis.

2.2. Image Acquisition Systems

ImageChecker 3D Calc CAD processes images originating from the following BT system:

- Hologic Selenia Dimensions licensed for Breast Tomosynthesis

If ImageChecker 3D Calc CAD results are not archived, they can be recreated later if the Raw Projection images have been archived or are still available on the BT system. The same results (ImageChecker 3D Calc CAD markings, PeerView data, etc.) should be generated each time the images are reprocessed. Be aware, however, that if the version of ImageChecker 3D Calc CAD algorithm is upgraded or the operating point is changed in the intervening period, the results may not be identical.

2.3. Inputs and Supported Views

ImageChecker 3D Calc CAD analyzes breast tomosynthesis datasets that conform to the DICOM standard. The software processes the following views:

LCC – Left Cranio-Caudal	RCC – Right Cranio-Caudal
LMLO – Left Medio-Lateral Oblique	RMLO – Right Medio-Lateral Oblique

m ***Important:*** *Be aware of the following:*

- ***Unsupported view modifiers.*** *ImageChecker 3D Calc CAD does not process datasets with any of the following view modifiers (with SNOMED codes):*
  - *Cleavage (R-102D2)*
  - *Magnification (R-102D6)*
  - *Spot Compression (R-102D7)*
- ***Breast implants.*** *ImageChecker 3D Calc CAD is not designed to process datasets acquired with an implant in view. If attempted, the algorithm may not produce results.*
- ***Partial views.*** *ImageChecker 3D Calc CAD is not designed to process partial views with an incomplete breast border. The algorithm may not produce results on partial view datasets.*

Chapter 3: Algorithm Description

This chapter describes the algorithm used by ImageChecker 3D Calc CAD when analyzing tomosynthesis datasets to detect calcifications.

3.1. Algorithm Overview

The ImageChecker 3D Calc CAD algorithm:

- Searches through breast tomosynthesis datasets for calcifications in the breast that may require further evaluation.
- Ranks its findings by certainty of finding (not related to probability of malignancy).
- Selects marks for display on those regions above a fixed threshold of certainty (one of three operating points).

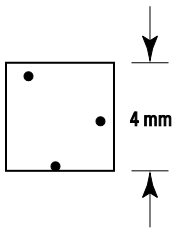
The algorithm offers three operating points to accommodate differing site preferences. The operating point is set on the server and cannot be set for each individual radiologist.

3.2. What the Algorithm Detects

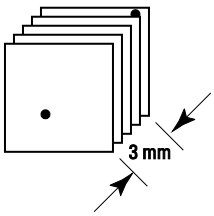
The ImageChecker 3D Calc CAD algorithm searches the tomosynthesis dataset for clusters of bright spots that are suggestive of calcification clusters.

The algorithm marks clusters with two or more elements, where each element is at least 100 microns in size. In addition, the elements must be separated by:

- No more than 4 mm if they are present within the same slice
- No more than 3 mm if they are in neighboring slices



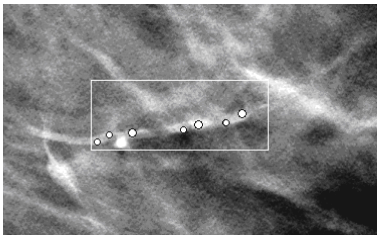
Elements within slice separated by 4 mm or less



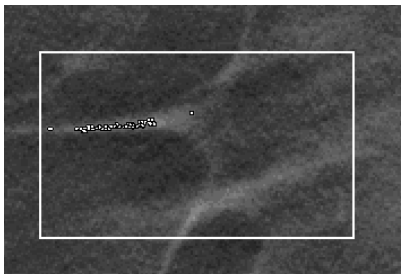
Elements in adjacent slices separated by 3 mm or less

The algorithm is designed to not mark obviously benign calcium elements such as popcorn calcifications and very high-contrast isolated benign elements such as surgical clips. However, the algorithm occasionally marks:

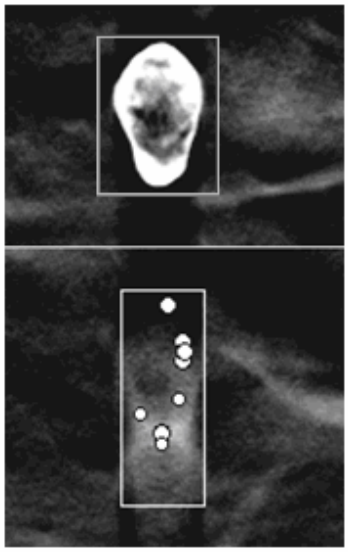
- Calcified arteries
- Rim benign calcifications
- Crossing structures and linear tissue strands
- Tomosynthesis reconstruction artifacts* generated by high-contrast objects such as large benign calcifications, large arterial calcifications, and surgical clips.



Calcified Artery



Crossing Linear Tissues

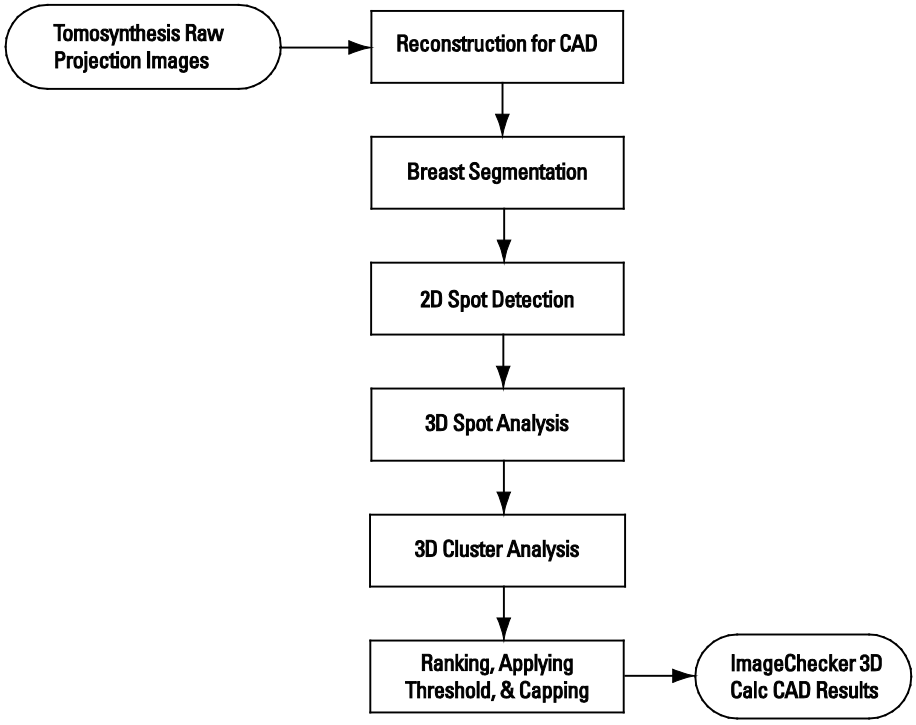


Reconstruction Artifacts*

* Artifacts resulting from the limited angular projection of tomosynthesis acquisition. These artifacts often appear on slices adjacent to high-contrast objects.

3.3. Detecting Calcifications

To detect calcifications, ImageChecker 3D Calc CAD performs a series of image analysis steps on the tomosynthesis Raw Projection images.



ImageChecker 3D Calc CAD Image Analysis

For each view, the ImageChecker 3D Calc CAD algorithm accepts a set of Raw Projection images. The algorithm:

- Generates a three-dimensional volume of reconstructed slice images suitable for analysis and identifies various areas in the image (such as the breast border and pectoralis muscle).
- Runs each image through a patented Shift-Invariant Artificial Neural Network (SIANN), a calcification detection filter that has been optimized using Hologic's training database.
- Analyzes the resulting initial candidates of 2D spots in the context of candidates from neighboring slices to identify 3D spots that are further grouped together into clusters based on predefined distribution criteria.
- Ranks the candidate clusters by their certainty of finding (not related to probability of malignancy) and applies a threshold according to the user-selected operating point. This involves eliminating all marks that have a lower value of certainty than the certainty corresponding to the user-selected operating point.
- Applies a capping rule to the list of clusters in order to reduce an excessive number of findings, as in cases with diffuse calcifications.

3.4. Operating Points

ImageChecker 3D Calc CAD allows each site to choose between three different operating points (i.e., algorithm thresholds). When selecting an operating point, clinicians must understand that a reduction of false marks will correspond to a reduction in detection sensitivity.

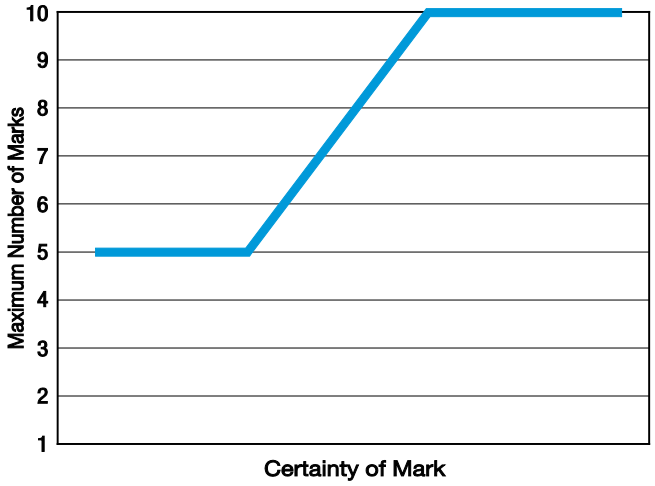
- Operating point 0 is best suited for sites that prefer the fewest false marks.
- Operating point 1 represents a balanced intermediate point.
- Operating point 2 is best suited for sites that prefer the highest detection sensitivity.

Each system is configured with operating point 2 by default. If you would like to change configurations, contact your Hologic Technical Service Representative.

3.5. Limiting the Number of Marks

In addition to applying the user-selected threshold, the software limits or 'caps' the number of marks for each view. The actual number of marks produced depends upon the individual subject and the current operating point. However, in order to avoid lengthy reading times, the algorithm applies a set of rules to limit the number of marks on each view.

The algorithm ranks all candidate marks by their certainty of finding (not related to probability of malignancy), and applies a threshold corresponding to the user-selected operating point. In each volume, the algorithm initially identifies up to five candidate marks eligible for display based on their ranking. The algorithm then identifies additional marks only if they exceed a predefined 'capping threshold'. Further, each additional mark must have a linearly increasing level of certainty as shown in the figure below. If these rules produce more than ten candidate marks, then the algorithm caps them irrespective of their certainty of finding.



Adaptive Thresholding for Volumes with Large Number of Marks

3.6. Examples of ImageChecker 3D Calc CAD Marks

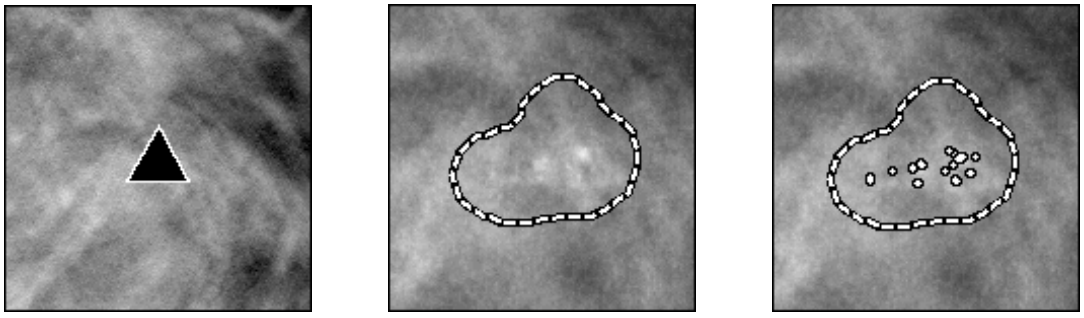
This section provides examples of ImageChecker 3D Calc CAD results as seen on Hologic SecurView review workstations (software versions 7.2 and later). SecurView provides a set of display technologies and controls for efficient reading workflow of ImageChecker 3D Calc CAD marks. SecurView uses graphic elements and controls to guide the reader through evaluation of the CAD marks.

As with two-dimensional CAD, you can enable or disable the display of CAD marks. Enabling tomosynthesis CAD display is a function that applies to all viewports that contain tomosynthesis images.

When viewing CAD marks for a calcification cluster, SecurView displays:

- The number of the currently selected CAD mark and the total number of detected clusters (for example, '1/3').
- Visual indicators that show the slices in which the CAD marks appear.
- In quadruple tiling mode, the RightOn CAD mark.
- In single or double-tiling mode, the CAD mark region outline, which appears around each calcification cluster.
- When selected by the user, PeerView 3D outlines around each detected calcification.

For more information about viewing ImageChecker 3D Calc CAD results, refer to the *SecurView User Manual*.



RightOn CAD Mark | Without PeerView 3D | With PeerView 3D

ImageChecker 3D Calc CAD Results

3.7. Reading Results

Hologic recommends that when reading with ImageChecker 3D Calc CAD, radiologists use a clinical protocol similar to that used with ImageChecker CAD for conventional mammography). A common reading scenario is as follows:

1. Read the case at the review workstation using your normal protocol. Make an initial interpretation.
2. Examine the images in detail and form a primary diagnosis.
3. Activate and view the CAD marks. Evaluate the ImageChecker data to determine whether other regions warrant further review.
4. Make a final assessment and create a report.

There is no clinical evidence available to date that indicates that ImageChecker 3D Calc CAD is a viable tool for use as a calcification 'first-reader'. Thus, Hologic does not recommend the use of ImageChecker 3D Calc CAD in place of human detection of calcifications. For more specific information about the limitations of the software, see **1.9 Warnings and Precautions**.

3.8. ImageChecker 3D Calc CAD Performance

Regulatory testing on this product involved 151 cases. Per DRD-00362 (as cited in VAR-02425), it was required that the testing verify the 3D CAD algorithm sensitivity for calcifications meets the requirements for all three operating points (i.e., are greater than or equal to the lower limit of the 95% confidence interval achieved by the previous release at similar false marker rates).

Table 1 Cenova 2.0 Tomosynthesis (3D) CAD algorithm (VAR-01930) result

Table 1	OP 0	OP 1	OP 2
Case Sensitivity	89% (134/151)	95% (143/151)	97% (146/151)
95% Confidence Intervals	83.70% - 93.78%	91.13% - 98.27%	93.83% - 99.54%
FP/View (Normal)	0.257 (103/400)	0.512 (205/400)	1.025 (410/400)

Table 2 ImageChecker 3D Calc CAD 1.1.0.8 algorithm result

Table 2	OP 0	OP 1	OP 2
Case Sensitivity	91% (137/151)	95% (143/151)	97% (147/151)
95% Confidence Intervals	86.10% - 95.35%	91.13% - 98.27%	94.79% - 99.91%
FP/View (Normal)	0.250 (100/400)	0.502 (201/400)	0.993 (397/400)

The data in Table 1 and Table 2 demonstrate that the ImageChecker 3D Calc CAD 1.1.0.8 algorithm sensitivity performance is greater than or equal to the lower limit of the 95% confidence interval achieved by the previous release at similar false marker rates for three operating points.

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