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**Characterization of indeterminate breast lesions on B-mode ultrasound using
automated machine learning models**

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For the original clinical trial that data was obtained from, the ultrasound contrast agent was provided by Lantheus Medical Imaging and the ultrasound scanner provided by GE Healthcare.

Conflict of Interest: None

Key words: Artificial Intelligence; Machine learning; Deep learning; Ultrasound imaging; Breast lesions

1 **Abstract**

2 Purpose: While mammography has excellent sensitivity for the detection of breast lesions,
3 its specificity is limited. Adjunct screening with ultrasound may partially alleviate this
4 issue, but also increases false positives, resulting in unnecessary biopsies. This study
5 investigated the use of Google AutoML Vision (Mountain View, CA), a commercially
6 available machine learning service, to both identify and characterize indeterminate breast
7 lesions on ultrasound.

8 Methods: B-mode images from 253 independent cases of indeterminate breast lesions
9 scheduled for core biopsy were used for model creation and validation. The performances
10 of two sub-models from AutoML Vision, the image classification model and object
11 detection model were evaluated, while also investigating training strategies to enhance
12 model performances. Pathology from the patient's biopsy were used as a reference standard.

13 Results: The image classification models trained under different conditions demonstrated
14 areas under the precision recall curve (AUC) ranging from 0.85 to 0.96 during internal
15 validation. Once deployed, the model with highest internal performance demonstrated a
16 sensitivity of 100% (95% confidence interval (CI) of 73.5-100%), specificity of 83.3%
17 (CI=51.6-97.9%), positive predictive value (PPV) of 85.7% (CI=62.9-95.5%), and
18 negative predictive value (NPV) of 100% (CI non-evaluable) in an independent dataset.
19 The object detection model demonstrated lower performance internally during
20 development (AUC=0.67) and during prediction in the independent dataset
21 (sensitivity=75.0% (CI=42.8-94.5), specificity=80.0% (CI=51.9-95.7), PPV=75.0%
22 (CI=50.8-90.0), NPV=80.0% (CI=59.3-91.7%)), but was able to demonstrate the location
23 of the lesion within the image.

24 Conclusions: Two models appear to be useful tools for identifying and classifying
25 suspicious areas on B-mode images of indeterminate breast lesions.

26

27 Keywords: Artificial Intelligence; Machine learning; Deep learning; Ultrasound
28 imaging; Breast lesions

29

30 **Introduction**

31 Breast cancer remains a primary health concern with 271,270 new cases diagnosed
32 and more than 42,260 deaths in 2019 in the United States alone.¹ When the patient presents
33 with metastases, the 5-year survival rate is only 26%.² However, early detection along with
34 appropriate therapy can reduce mortality significantly.³ Screening mammography remains
35 the best modality for breast cancer detection with an overall sensitivity > 85%. However,
36 in women with dense breasts, which make up more than 40% of women in the United
37 States, the sensitivity lowers to as low as 48%.⁴ While adjunct screening with ultrasound
38 imaging improves the sensitivity for cancer detection, the cost is reduced specificity:
39 increased non-cancer recalls and more benign biopsies.⁵

40 The Breast Imaging Reporting and Data System (BI-RADS®) is used by
41 radiologists to classify breast lesions into several risk categories with different expected
42 probabilities of malignancy. The course of clinical management is based on risk categories⁶,
43 with malignancy confirmed by biopsy. Nonetheless, even with using the BI-RADS data,
44 inter and intra observer variability exists in classifying lesions and over 70% of all breast
45 biopsy results are benign.⁷ Thus, a better approach to differentiate between benign and
46 malignant lesions from ultrasound images is needed.

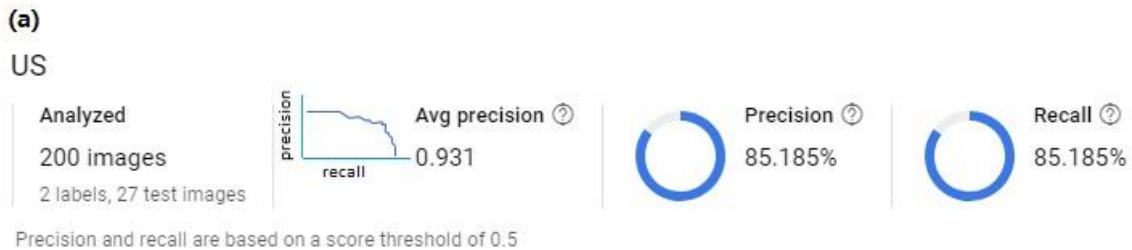
47 The use of artificial intelligence (AI) in radiology has the potential to reduce costs,
48 save time, and improve diagnostic accuracy.⁸ Multiple studies have shown that deep
49 learning algorithms (one type of AI) outperform experienced radiologists in the diagnosis
50 of breast lesions with 5-13% larger area under the receiver operating characteristic (ROC)
51 curves.^{9,10,11} However, using deep learning algorithms requires a large amount of data (e.g.,
52 5,000-10,000 training images) and training a new deep learning algorithm is both time-
53 consuming and expensive. Several commercially AI programs are available providing an
54 opportunity to overcome these barriers. Google AutoML Vision (Google, Mountain View,
55 CA) is a machine learning service from Google Cloud Platform that runs deep learning
56 algorithms online and performs image-classification and image-recognition tasks on cloud
57 services, reducing the need for expensive hardware. It enables a customized model to be
58 created quickly by leveraging transfer learning and neural architecture search technologies,
59 which can lead to more accurate results with less misclassifications than other generic
60 machine learning services.^{12,13} In addition, due to the transfer learning component, which
61 takes the advantages of lower-level features from pre-trained convolutional neural
62 networks (CNN), significantly fewer images are required for algorithm training.¹¹

63 Several sub-models are currently available for beta testing including an image
64 classification mode and an object detection model. These models may provide distinct but
65 useful roles within the field of radiology. The image classification model can train models
66 to classify images (in this example cancer vs. not cancer), while the object detection model
67 can be used to detect objects within an image and then assign a confidence score for a
68 specific classification (in this example the likelihood of lesion being cancerous). Each of
69 these sub-models perform self-validation and self-testing during the training process and
70 generate model performance reports based on the training data (Figure 1).

71 While this technology has been used for a variety of product management
72 applications, its use in radiological applications is relatively unexplored.^{12,13} Thus, the
73 purpose of this study was to evaluate the performance of both AutoML Vision's image
74 classification and object detection models for the characterization of intermediate breast
75 masses imaged with B-mode ultrasound. Specifically, we strove to identify the

76 performance of AutoML’s image classification and object detection mass for classifying
 77 breast masses as cancerous or non-cancerous in a population of suspicious masses
 78 scheduled for tissue biopsy. The influence of category balancing and image cropping on
 79 model performance was also investigated.

80
 81



(b)

Important parameters	Description
Score thresholds	A minimal score for model to classify images to its correct labels. Score range: 0 to 1
Average Precision (AUC)	How well model performs across all score thresholds, area under precision-recall tradeoff curve. Range: 0 to 1
Precision (Positive Predict Value)	Higher precision, fewer false positives. Increase score threshold increase precision but lower recall. Range: 0 to 1
Recall (Sensitivity)	Higher recall, fewer false negatives. Lower score threshold increase recall but lower precision. Range: 0 to 1

82
 83 **Figure 1.** (a) A model performance report is generated after each training process (b)
 84 Parameter descriptions and their equivalent ROC terminologies.

85

86 **Material and Methods**

87 *Clinical studies*

88 To create training datasets for the AI image classification and object detection
 89 models, ultrasound images were extracted from two previous clinical studies. The first
 90 study was a multi-center clinical trial that was approved by the Institutional Review Boards
 91 of Thomas Jefferson University (TJU) and The University of California, San Diego (UCSD)
 92 and conducted between January 2011 and December 2015 in which contrast-enhanced
 93 ultrasound was used to characterize indeterminate breast masses scheduled for biopsy.^{14,15}
 94 The second study was approved by the Institutional Review Boards of TJU and conducted
 95 between May 2014 and February 2016, in which a contrast-enhanced ultrasound technique
 96 was used to predict the response of breast cancer to neoadjuvant chemotherapy¹⁶. All
 97 patients from both studies provided written informed consent before participating. The
 98 imaging data for both studies were acquired using a commercially available Logiq 9
 99 scanner (GE Healthcare, Waukesha, WI) equipped with a 4D10L probe and imaging
 100 parameters were optimized on an individual basis according to good clinical practice. There
 101 were 236 women enrolled in the first clinical study with an average age of 52 ± 13 years.
 102 The average lesion cross-sectional areas for malignant and benign lesions were $190.1 \pm$
 103 35.7 mm^2 and $124.1 \pm 15.5 \text{ mm}^2$, respectively. The second clinical study enrolled 17
 104 participants who had invasive ductal carcinomas with an average age of 52.9 ± 10.4 years
 105 and an average lesion cross-sectional area of $604.6 \pm 460.7 \text{ mm}^2$. In total, there were 253
 106 cases. For this AI processing study, 242 patient cases with available biopsy results
 107 (reference standard) were selected. Within these 242 cases, 21 cases were then excluded

108 by a blinded radiologist due to poor image quality resulting in 154 unique patients with
109 benign breast lesions and 67 unique patients with malignant breast lesions (221 in total).

110

111 *Data preprocessing*

112 The B-mode ultrasound data were originally stored in DICOM format. A
113 radiologist (S.N) with more than 10 years of experience in breast ultrasound who was
114 blinded to pathology results selected representative views from each CINE loop for the 221
115 cases. The DICOM data were viewed with RadiAnt DICOM Viewer (4.6.9, Medixant,
116 Poznan, Poland) software and selected images were stored into JPG format in order to meet
117 the input format requirements for Google AutoML Vision. Images were further cropped
118 using Matlab (2016a, The Mathworks Inc., Natick, MA) to generate three different groups
119 of training data: Annotated (A; with black and white scale, depth scale, GE label and
120 ultrasound image), de-Annotated (deA; scales and GE label were removed, ultrasound
121 images only), and Lesion Only (LO; lesions were extracted from the ultrasound images).
122 Example images for each three training groups are shown in Figure 2.

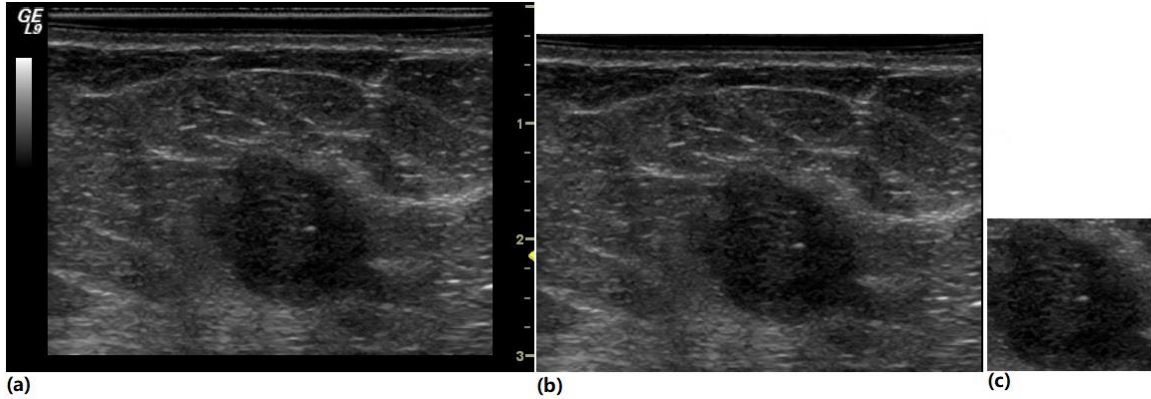
123 Based on model recommendations, 26 out of the 221 cases (19 malignant and 7
124 benign cases corresponding to 11% of the patients) were reserved to form an independent
125 prediction dataset to evaluate the models' performance. In order to augment our prediction
126 dataset, a second radiologist (E.Q) with over 10 years of experience in breast ultrasound
127 selected 5-7 image from each of the 26 test cases. This resulted in a final prediction dataset
128 of 154 images for prediction testing. The same prediction dataset was used to evaluate all
129 models from both image classification and object detection. Additionally, findings were
130 grouped on a lesion by lesion basis to evaluate model intra-reader agreement (i.e., the
131 ability to predict malignancy in separate images from the same case).

132

133 *Image Classification Model Training*

134 The Google AutoML Vision Image Classification Model was first investigated for
135 its ability to differentiate benign (non-cancerous) from malignant (cancerous) breast
136 lesions within the population of suspicious masses referred for biopsy. This model requires
137 input training data of at least 100 images from each outcome group for training. However,
138 as there were only 48 unique patients with malignant lesions remaining in the overall
139 dataset after excluding the 19 malignant cases that were used for independent testing, a
140 radiologist (S.N) selected at least two images from the malignant lesion dataset.
141 Consequently, the final training data for the image classification model consisted of 147
142 images of benign breast lesions and 117 images of malignant lesions (264 images in total).

143 The training data for the model was slightly unbalanced (with 147 in the benign
144 group and 117 in the malignant group), which may impact the performance of the model.¹⁷
145 Thus, 30 random benign images were removed from the data set in order to compare the
146 impact of unbalanced training (147 benign lesion images vs. 117 images of malignant
147 lesions) relative to balanced training (117 benign lesion images vs. 117 malignant lesion
148 images) on the performance of the model. Therefore, in addition to three different training
149 groups (Annotated, de-Annotated, and Lesion Only; Figure 2), 6 customized models were
150 trained. These groups are summarized in Table 1.



151

152 **Figure 2.** Example of the varying degrees of image cropping showing (a) the annotated
 153 image (A) containing the black and white scale bar, depth scale, GE label and ultrasound
 154 image, (b) the deAnnotated image (deA), in which the scales and GE label were removed
 155 leaving only the full ultrasound image, and (c) the lesion only (LO) image consisting of
 156 only the cropped breast mass.

157 **Table 1.** Summary of training data sets used for unbalanced (UB) and balanced (B)
 158 conditions. A stands for annotated images, deA stands for de-annotated images, and LO
 159 stands for lesion only images.

Unbalanced training	
Customized model	Training Data Information (Number of benign lesion images, number of malignant lesion images, image group)
A_UB	147 Benign, 117 Malignant, Annotated
deA_UB	147 Benign, 117 Malignant, deAnnotated
LO_UB	147 Benign, 117 Malignant, Lesion Only
Balanced training	
Customized model	Training Data Information (Number of benign lesion images, number of malignant lesion images, image group)
A_B	117 Benign, 117 Malignant, Annotated
deA_B	117 Benign, 117 Malignant, deAnnotated
LO_B	117 Benign, 117 Malignant, Lesion Only

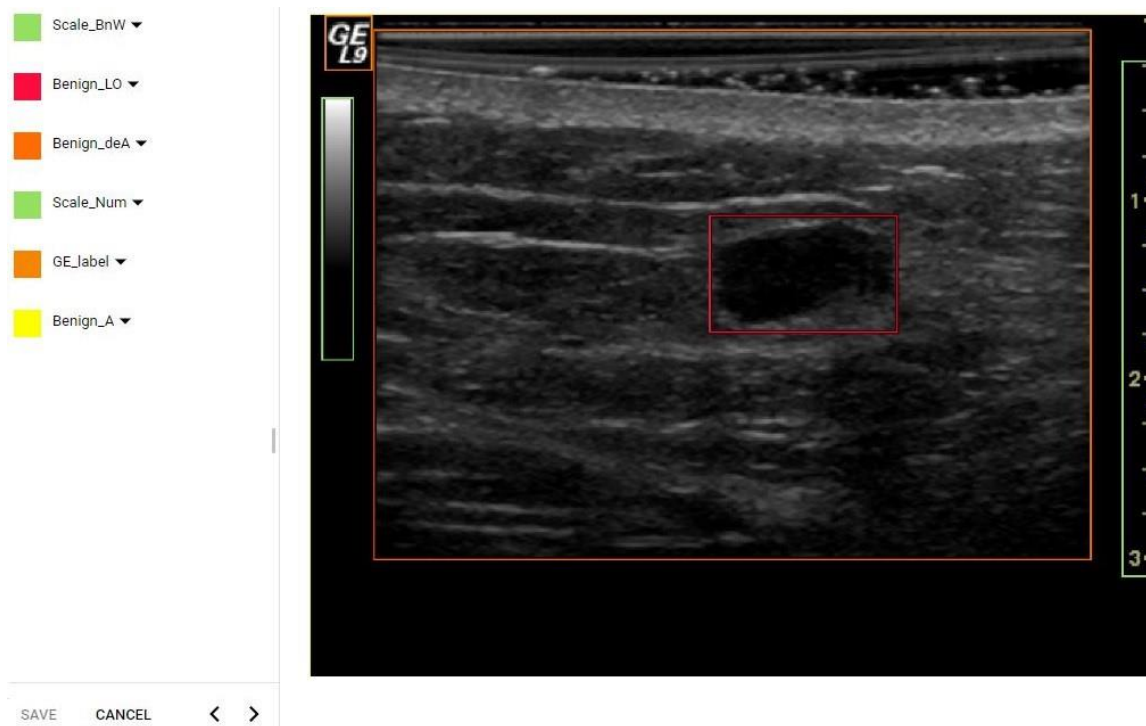
160

161 *Object Detection Model Training*

162 The Google AutoML Vision Object Detection Model was investigated to determine
 163 the ability of this algorithm to first identify the suspicious breast mass, then subsequently
 164 assign a risk score on the likelihood of the image containing breast cancer. To train the

165 object detection model, the same training data (147 benign and 117 malignant breast lesion
166 images) as well as the same prediction images (154 breast images) described above were
167 utilized. Data was first uploaded into Google Cloud Storage and then an Excel file that
168 contained pathways for importing each image was generated from Python. The object
169 detection model processes training image data within the model by using bounding boxes
170 and labels to select objects that were important and intended to be detected inside an image.
171 Therefore, only the full annotated images were imported into the model. Following upload,
172 the model was trained by a blinded radiologist to identify the scale bars and manufacturer
173 labels (as an algorithm validation check) and either malignant or benign masses within the
174 three cropping approaches described above. An example of this training is provided in
175 Figure 3.

176



177

178 **Figure 3.** Example figure showing image uploading and object identification training.
179 Annotated images were imported into the object detection model during training and image
180 labeling performed within the model. Labels were then manually added as shown on the
181 left side by placing rectangle bounding boxes to on the desired objects as shown on the
182 right side.

183 *Evaluation of Model Performance*

184 The performance of each model was evaluated using results from the participant's
185 tissue biopsy as a reference standard. Performance reporting was separated by internal
186 performance (self-reported by the model during training) and external prediction within the
187 dataset reserved for testing. For internal validation, the area under the precision recall curve,
188 sensitivity, specificity, negative predictive value, and positive predictive value were all
189 reported with 95% confidence intervals. Model agreement was calculated for each of the
190 six image classification models and the object detection model by quantifying the rate of

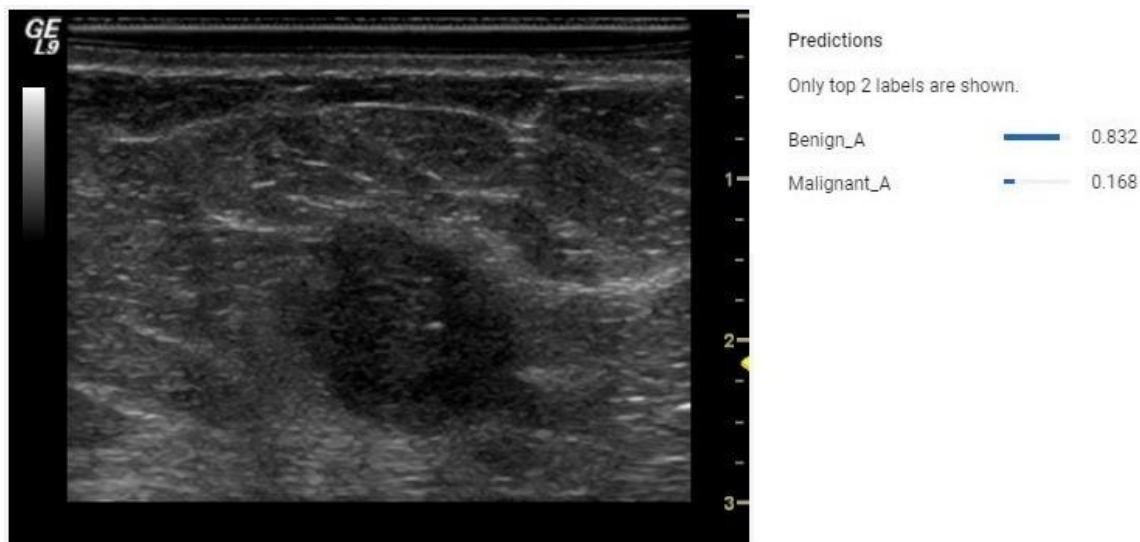
191 agreement amongst images taken from the same lesion for each of the 26 external
192 prediction cases. All statistical analysis was performed in GraphPad Prism Version 8.0
193 (San Diego, CA) with comparisons across multiple groups performed using a one-way
194 ANOVA and direct comparisons between individual groups determined using a Student's
195 t-test. Statistical significance was determined using $p < 0.05$.

196

197 **Results**

198 *Image Classification Model Performance*

199 Following training of the image classification model, internal performance reports
200 were generated for each of the training conditions summarized in Table 1. Model
201 performance reports from these six conditions are shown in Table 2. For external validation
202 the model was deployed, and the 154 independent images analyzed. Figure 4 shows one
203 prediction example from a model providing confidence scores for different labels. In order
204 to draw decisions from the prediction results, a confidence score of 0.72 was utilized. This
205 cutoff criteria was initially optimized by the model software based on optimization of the
206 ROC curve during training and adjusted to minimize the number of cases in which a
207 decision could not be made, while also mimicking the prevalence of malignancy in the
208 prediction dataset. The decision for the prediction (either malignant or benign) relied on
209 the label that had a confidence score greater than 0.72. If a prediction generated a
210 confidence scores lower than 0.72 or if it generated both malignant and benign labels higher
211 than 0.72, the prediction was considered as a not-applicable (N/A) case. The sensitivity,
212 specificity, positive predictive value, negative predictive value, 95% confidence interval
213 values and number of N/A cases for the 154 prediction images at a confidence score
214 threshold of 0.72 are shown in Table 3.



215

216 **Figure 4.** Example result from the image classification model during the post-training
217 prediction phase of a benign mass. From the model's perspective, it had 83.2% certainty
218 that the lesion was benign and 16.8% certainty that the lesion was malignant.

219

220 **Table 2.** Internal model performance reports obtained during model training from the 6
221 customized image classification models. AUC: Area under the precision recall curve. PPV:

222 Positive predictive value. NPV: Negative predictive value. 95% CI: 95% Confidence
 223 Interval.

Customized Models	AUC	Sensitivity(%) 95% CI	Specificity(%) 95% CI	PPV (%) 95% CI	NPV(%) 95% CI
A_UB	0.871	63.6 (30.8 - 89.1)	83.3 (51.6 - 97.9)	77.8 (47.8 - 93)	71.5 (52.4 - 85.1)
A_B	0.882	72.7 (39.0 - 94.0)	80.0 (51.9 - 95.7)	72.7 (47.6 - 88.7)	80 (59.6 - 91.6)
deA_UB	0.955	100.0 (73.5- 100.0)	86.7 (59.5 - 98.3)	85.7 (62.2 - 95.6)	100.0 non-evaluable*
deA_B	0.966	100.0 (73.5 - 100.0)	83.3 (51.6 - 97.9)	85.7 (62.9 - 95.5)	100.0 non-evaluable*
LO_UB	0.911	80 (44.4 - 97.5)	76.5 (50.1 - 93.2)	66.6 (44.5 - 83.2)	86.7 (64.7 - 98.9)
LO_B	0.853	81.8 (48.2 - 97.7)	76.9 (46.2 - 94.7)	75.0 (51.7 - 89.4)	83.4 (58.0 - 94.8)

224 * NPV non-evaluable due to lack of false negative cases.

225

226 **Table 3.** The calculated sensitivity, specificity, positive predictive value (PPV), and
 227 negative predictive value (NPV), for all customized image classification models as well
 228 as number of N/A cases in the prediction (post-training) dataset. 95% CI: 95%
 229 Confidence Interval.

Models	Sensitivity(%) 95% CI	Specificity(%) 95% CI	PPV(%) 95% CI	NPV(%) 95% CI	# of N/A
A_UB	75.2 (66.4 - 82.7)	51.5 (33.5 - 69.2)	80.8 (74.4 - 85.8)	43.6 (32.7 - 54.8)	4
A_B	70.4 (61.2 - 78.6)	63.9 (46.2 - 79.2)	84.1 (77.1 - 89.2)	44.2 (35.5 - 53.7)	3
deA_UB	83.1 (75 - 89.3)	36.1 (20.8 - 53.8)	77.9 (73.1 - 82.0)	44.1 (30.4 - 58.7)	0
deA_B	81.9 (73.7 - 88.4)	36.1 (20.8 - 53.8)	77.6 (72.8 - 81.8)	42.5 (29.2 - 56.9)	2
LO_UB	78.9 (70.3 - 86.0)	76.5 (58.8 - 89.3)	90.1 (83.1 - 94.4)	57.3 (47.4 - 66.7)	6
LO_B	87.8 (80.4 - 93.2)	12.9 (3.63 - 29.8)	73.2 (70.1 - 76.0)	28.2 (12.2 - 52.5)	8

230

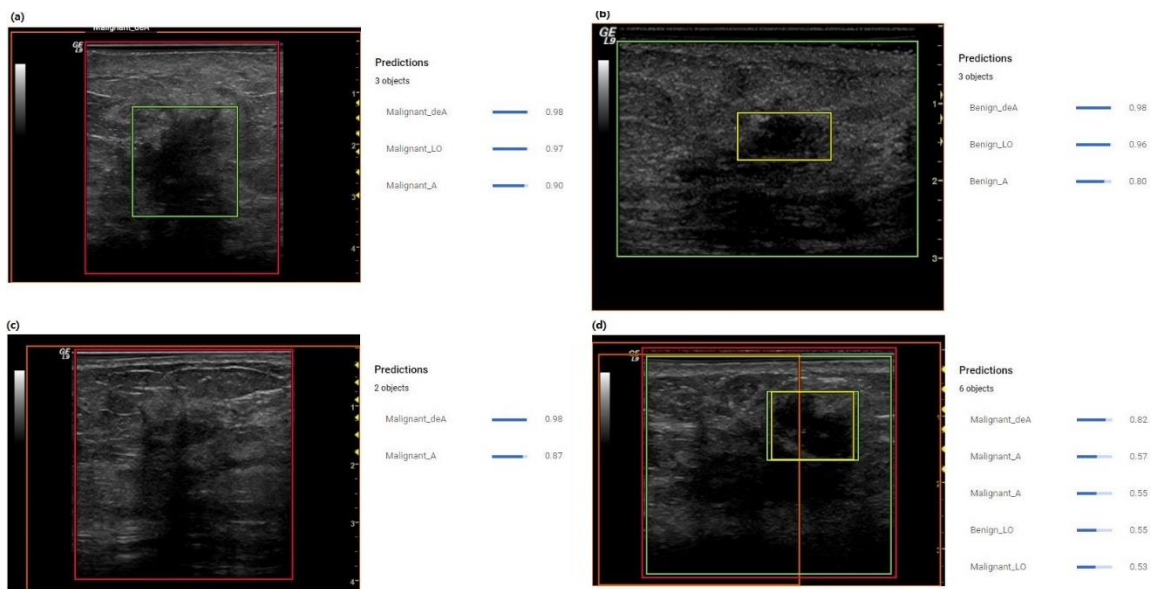
231 *Object Detection Model Performance*

232 Annotated images from the training dataset were uploaded into the Google Cloud
 233 platform and the object detection model trained as described above. The internal
 234 performance report during training is provided in Table 4.

235 **Table 4.** Internal performance report from the object detection model during training.
 236 AUC: Area under the precision recall curve. PPV: Positive predictive Value. NPV:
 237 Negative predictive value. 95% CI: 95% Confidence Interval.

Score Threshold	AUC	Sensitivity(%) 95% CI	Specificity(%) 95% CI	PPV(%) 95% CI	NPV(%) 95% CI
0.47	0.667	75.0 (42.8 - 94.5)	80.0 (51.9 - 95.7)	75.0 (50.8-90.0)	80.0 (59.3-91.7)

238
 239 Following training, the 154 prediction images were uploaded into the model and
 240 the predictions showed three distinct behaviors. In the first behavior, the model detected
 241 the lesions as well as the area where the lesion was located using the bounding boxes and
 242 provided confidence scores (Figure 5a, 5b). In the second behavior, the model detected no
 243 distinct lesion but predicted either benign or malignant areas within the image (Figure 5c).
 244 In the third behavior, the model detected lesions but assigned both malignant and benign
 245 labels to the lesions with different confidence scores (Figure 5d). The performance metrics
 246 of the object detection model within the independent prediction dataset is provided in Table
 247 5.
 248



249
 250 **Figure 5.** (a) Example case where the model detected both lesion and suspicious areas in
 251 the image with confidence scores of 0.97, 0.98 and 0.9. The position of the malignant
 252 lesion was marked by the green color bounding box drawn by the model. (b) Example
 253 case where the model detected both lesion and suspicious areas in the image with
 254 confidence scores of 0.96, 0.98 and 0.8 for the lesion and areas to be benign. The position
 255 of the benign lesion was marked by the yellow bounding box drawn by the model. (c)
 256 Example case where the model detected no lesions but malignant areas with confidence
 257 scores of 0.98 and 0.87. (d) The model detected the lesion but assigned both malignant

258 and benign labels. The model provided a confidence score of 0.55 for the lesion to be
 259 benign and a confidence score of 0.53 for the lesion to be malignant. The model also
 260 indicated malignant areas with confidence score of 0.82 and 0.57.

261

262 **Table 5.** The calculated sensitivity, specificity, positive predictive value (PPV), and
 263 negative predictive value (NPV) for the object detection model in the prediction (post-
 264 training) dataset. 95% CI: 95% Confidence Interval.

Score Threshold	Sensitivity(%) 95% CI	Specificity(%) 95% CI	PPV(%) 95% CI	NPV(%) 95% CI	# of N/A
0.72	78.8 (70.3 - 85.8)	69.4 (51.9 - 83.7)	87.5 (80.9-92.0)	54.8 (44.6 - 64.6)	0

265

266 *Rate of Prediction Agreement*

267 The presence of multiple images and predictions (5-7) from each independent case
 268 (n=26) allowed for quantification of intra-reader agreement of each model. This data is
 269 summarized in Table 6. All models demonstrated a reasonably high rate of agreement, with
 270 no statistical difference observed across models (p=0.8).

271

272 **Table 6.** Average percentage of model prediction agreement with standard deviation across
 273 the 26 cases for all models.

Models	Prediction Agreement
OBJ	88 ± 18.2%
A_B	82 ± 18.1%
A_UB	87 ± 16.7%
deA_B	88 ± 13%
deA_UB	90 ± 13%
LO_B	86 ± 22%
LO_UB	89 ± 16.5%

274

275 **Discussion**

276 Ultrasound is a nonionizing, readily available, low-cost, and real-time imaging
 277 modality that has shown good diagnostic performance in breast cancer detection and
 278 diagnosis. In recent years, radiologists have explored the potential of AI technology to
 279 improve clinical practice, including the accuracy of ultrasound for breast cancer
 280 diagnosis.^{9,10,11} Google AutoML Vision, released in 2018, may aid in the characterization
 281 of indeterminate breast masses by building of customized image-classification and image-
 282 recognition models on cloud services. Thus, this study explored the potential of AutoML
 283 Vision to classify and evaluate breast ultrasound images, using its image classification and
 284 object detection model.

285 Within the image classification model, 6 different training data setups were
 286 investigated. Performance during internal testing from these methods was similar with
 287 areas under the precision recall curve ranging from 0.85 to 0.96, indicating the influence

288 of label balancing and image cropping were negligible in this dataset. The object detection
289 model had an area under the precision recall curve of 0.67 during internal validation. While
290 this performance is less encouraging than the classification model, the object detection
291 could locate the position of lesion in the image. It is anticipated that this will enable
292 radiologist adoption by providing a clear rationale for diagnosis while also streamlining
293 workflow.

294 Comparing the performance of LO_UB with prior studies on classifying B-mode
295 ultrasound breast mass using deep learning algorithms, the 91.1% AUC was similar to the
296 89.6% AUC from Cheng et al.¹⁸ and 93.6% from Byra et al.¹⁰ but lower than the 96% from
297 Han et al.¹⁸ or the 99% reported by Yap et al.¹⁹ Importantly however, studies that have
298 reported exceptional overall AUCs have employed datasets consisting of large numbers of
299 lesions that were clearly benign (BI-RADS < 3) or highly likely to be malignant (BI-RADS
300 5)^{19,20}. Data from our study primarily consisted of indeterminate breast masses scheduled
301 for biopsy in which lower performance is expected, but this scenario more closely
302 resembles the clinical need for improved diagnosis. Therefore, we believe the image
303 classification model provides acceptable diagnostic performance under the appropriate
304 training setups.

305 While encouraging, several limitations exist and should be addressed in the future.
306 Within the object detection model, the input regions of interest are required to be in
307 rectangular shape. The result of this is that all LO images will contain surrounding tissue.
308 Based on the size and shape of the lesion, the amount of surrounding tissues could vary,
309 which may introduce unwanted variability. Thus, potential improvement maybe achieved
310 by allowing customize-shaped input images for the model or automatic segmentation prior
311 to image upload. Meanwhile, more training images could be added to increase the model
312 performance as only 264 training images were used in study. Finally, while the AutoML
313 program stresses ease of use and off-the shelf capabilities, its limited flexibility also results
314 in limitations compared to traditional AI platforms^{21,22}. For example, traditional methods
315 of sample size augmentation and testing such as leave-one-out cross-validation methods
316 cannot be used in applications where multiple images/lesion are generated without
317 compromising independence. Additionally, once the model is deployed it provides a binary
318 decision on images used for prediction, which prohibits traditional performance
319 evaluations such as areas under the ROC and precision-recall curves. Despite these
320 limitations, results to date are encouraging and the platform should be further explored
321 moving forward.

322

323 **Conclusion**

324 The Google AutoML Vision platform showed an acceptable performance to
325 classify breast ultrasound images under appropriate training setups and the use of both the
326 Image Classification and Object Detection Models should be further explored. The
327 platform also showed cost-effective advantage as all customized models were run on cloud
328 services minimizing local hardware requirements. Our results indicated the platform could
329 potentially be a useful tool in assisting radiologists in the characterization of indeterminate
330 breast masses identified during screening. Ultimately, this approach could reduce the
331 number of unnecessary biopsies.

332

333 **Conflicts of Interest**

334 For the original clinical trial that data was obtained from, the ultrasound contrast
335 agent was provided by Lantheus Medical Imaging and the ultrasound scanner provided
336 by GE Healthcare. No other conflicts of interest are declared.

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