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Rescuing the Clinical Breast Examination:

Advances in Classifying Technique and Assessing Physician Competency

Shlomi Laufer, PhD[*,†], **Anne-Lise D. D'Angelo, MD**[*], **Calvin Kwan, BS**[*], **Rebbeca D. Ray, PhD**[*], **Rachel Yudkowsky, MD, MHPE**[‡], **John R. Boulet, PhD**[§], **William C. McGaghie, PhD**[¶], and **Carla M. Pugh, MD, PhD**[*]

[*]Department of Surgery, University of Wisconsin-Madison, Madison, WI

[†]Department of Electrical and Computer Engineering, University of Wisconsin-Madison, Madison, WI

[‡]Department of Medical Education, University of Illinois at Chicago College of Medicine, Chicago, IL

[§]Foundation for Advancement of International Medical Education and Research, Philadelphia, PA

[¶]Department of Medical Education, Northwestern University Feinberg School of Medicine, Chicago, IL

Abstract

Objective—Develop new performance evaluation standards for the clinical breast examination (CBE).

Summary Background Data—There are several, technical aspects of a proper CBE. Our recent work discovered a significant, linear relationship between palpation force and CBE accuracy. This article investigates the relationship between other technical aspects of the CBE and accuracy.

Methods—This performance assessment study involved data collection from physicians (n = 553) attending 3 different clinical meetings between 2013 and 2014: American Society of Breast Surgeons, American Academy of Family Physicians, and American College of Obstetricians and Gynecologists. Four, previously validated, sensor-enabled breast models were used for clinical skills assessment. Models A and B had solitary, superficial, 2 cm and 1 cm soft masses, respectively. Models C and D had solitary, deep, 2 cm hard and moderately firm masses, respectively. Finger movements (search technique) from 1137 CBE video recordings were independently classified by 2 observers. Final classifications were compared with CBE accuracy.

Results—Accuracy rates were model A = 99.6%, model B = 89.7%, model C = 75%, and model D = 60%. Final classification categories for search technique included *rubbing movement, vertical movement, piano fingers*, and *other*. Interrater reliability was (k = 0.79). *Rubbing movement* was 4

Reprints: Carla M. Pugh, MD, PhD, Department of Surgery, University of Wisconsin-Madison, 600 Highland Ave, H4/785B, Madison, WI 53715; pugh@surgery.wisc.edu.

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times more likely to yield an accurate assessment (odds ratio 3.81, $P < 0.001$) compared with *vertical movement* and *piano fingers. Piano fingers* had the highest failure rate (36.5%). Regression analysis of search pattern, search technique, palpation force, examination time, and 6 demographic variables, revealed that search technique independently and significantly affected CBE accuracy ($P < 0.001$).

Conclusions—Our results support measurement and classification of CBE techniques and provide the foundation for a new paradigm in teaching and assessing hands-on clinical skills. The newly described piano fingers palpation technique was noted to have unusually high failure rates. Medical educators should be aware of the potential differences in effectiveness for various CBE techniques.

Keywords

clinical breast examination; clinical competence; educational measurement; palpation; performance standards; sensor technology; simulation

The utility of the clinical breast examination (CBE) has been questioned for several years. Published guidelines from the United States Preventive Task Force[1,2] cite insufficient evidence to support use of CBE. Moreover, the American Cancer Society[3] does not support routine CBE as a screening method for women with average risk. These recommendations are based on multiple studies comparing CBE accuracy to other screening modalities and evaluating CBE influence on breast cancer mortality. Although these studies provide evidence-based data regarding the correlation between CBE screening and clinical outcomes, they do not take into account the wide variation in CBE techniques and different levels of expertise in performing the CBE.

In our recent study using a sensor-enabled breast simulator with 553 physicians, we showed that palpation force has a significant and linear relationship with CBE accuracy.[4] This study defined a specific range of palpation forces that increase the likelihood of an accurate CBE. Forces below 10 N correlated significantly with inaccurate examinations and forces above 17 N did not provide incremental performance benefits. The study showed that about 15% of practicing physicians are at high risk for missing a deep mass due to insufficient palpation force. This suggests that assessing the usefulness of the CBE should take into account the technique used and the competency of the health care provider performing the examination.

Performance metrics and feedback on physical examination skills have traditionally been based on expert ratings and group consensus derived from direct observation. More recently, medical simulation technology has introduced broader options and techniques for clinical performance assessment.[5–7] It is noted that other highly skilled professions have a long history of using a wide variety of performance measurement approaches. For example, video review has been an important tool in assessing expert performance in sports such as football, golf, and gymnastics[8–11] In addition to video, other technologies such as sensors and motion tracking have enabled the development of more precise and detailed performance metrics[12–14]

Current recommendations for performing the CBE include (a) use of a “vertical strip” search pattern, (b) use of the pads of the middle 3 fingers in a circular motion, (c) use of increasing levels of pressure, and (d) use of an examination time of 3 minutes per breast.[15–17] Adherence to these recommendations has been reported to result in increased accuracy. However, “increasing levels of pressure” is subjective and poorly assessed by observation. Even with accurate measurement of pressure on simulation models, objective feedback about pressure levels alone may not provide sufficient detail to result in an optimal and effective breast examination. More work is needed to translate these findings into meaningful performance metrics for training and remediation.

This study used video classification to explore the relationship between CBE search technique and accuracy. We hypothesized that independent of palpation force, specific CBE hand and finger movements used while searching for breast masses will have significant effects on CBE accuracy. As part of the research protocol, practicing physicians performed simulated CBE’s under conditions that mimic an office visit for a symptomatic patient.

METHODS

Study Design

This was a single observation, performance assessment study.[18] The University of Wisconsin Institutional Review Board approved the study.

Participants

A convenience sample of physicians (n = 553) was recruited at each of 3 annual clinical meetings: the American Society of Breast Surgeons, Chicago, IL, 2013 (n = 136); the American Academy of Family Physicians, San-Diego, CA, 2013 (n = 236); and the American College of Obstetricians and Gynecologists, Chicago, IL, 2014 (n = 181). The target population was physicians who perform the CBE in routine practice. Nonphysician health care providers, residents, and medical students were excluded.

Sensor-enabled Breast Models

The breast examination models are part of a wide range of simulators previously developed and evaluated for research and assessment purposes.[19–24] Standardized molding techniques allow for fabrication of different clinical presentations and standardization of components. All models consist of a multilayered custom breast mold integrated with a sensor mapping system that provides coverage of the entire base. The sensor mapping system includes a 25 × 25 cm ultrathin, tactile pressure sensor with 1936 individual sensing elements uniformly distributed in a 44 × 44 grid (Tekscan, Boston, MA). Data sampling rate was 90Hz.[28] Time to perform a complete CBE (CBE time), area covered (percentage), and average force (N) were calculated.

Four clinical presentations were used[4] (Fig. 1):

1. Model A: dense left breast with a soft, well-circumscribed 2 cm × 2 cm spherical mass, superficially located in the upper outer quadrant.

2. Model B: same as model A except that the mass was half a sphere (2 cm × 1 cm).
3. Model C: dense right breast with a 2-cm, irregular border, hard mass located near the chest wall in the lower outer quadrant.
4. Model D: same as model C except the 2-cm mass was molded from a softer silicone derivative instead of hard clay.

Protocol

Data were collected at designated exhibit booths containing 2 or 4 sensor-enabled breast models. Recruitment involved asking exhibit hall visitors, "Do you perform the clinical breast examination in your practice?" Interested participants were given background information on the study and then completed a 1-time demographic survey. Participants were informed that the simulated patient believes she felt a mass on self-examination. However, now that she is in clinic, she is currently unable to demonstrate or locate the lesion. At each station, the participant reviewed a clinical scenario, performed a CBE, and documented their findings on a clinical assessment form. Progression through the stations was randomized. Participants' CBE performance was video recorded simultaneously with sensor data recordings. The goal of this study was to capture CBE technique while clinicians were purposefully seeking a mass.

Measurements

Four types of measurement data were collected:

1. Demographic Surveys: Gender, years of practice, clinical specialty, number of CBEs performed per week (0–5, 6–10, 11–20, >20), experience with teaching CBEs (Y/N) and experience using breast models (Y/N).
2. Clinical Documentation Form: participants indicated whether they found a breast lesion by circling "mass" or "no mass." Participants also marked the location of their findings on a diagram of the breast. Accuracy required both items to be completed correctly, that is, circled "mass" and marked the correct location of the mass on the diagram within a 3-cm radius.
3. Video Data: Videos were reviewed and coded by a single, blinded rater. A 30% random sample was reviewed and classified by a second blinded rater to assess interrater agreement. *Search pattern* was defined by the direction of exploration and was classified as (a) circular, (b) radial, (c) linear, or (d) other based on the first 30 seconds of the video recording. A linear search pattern was defined as examination of the breast by proceeding in vertical or horizontal strips across the chest wall.[15–17] A circular search pattern was defined as examination of the breast in concentric circles.[15–17] A radial search pattern was defined as examination of the breast as wedges of tissue in a radial fashion.[15–17]

   Unlike *search pattern, search technique* is not a commonly described component of the CBE. Using nomenclature and categories from the object recognition literature, we defined *search technique* as the finger movements used by the examiner.[25] These finger movements are independent of the direction of exploration (*search pattern*). *Search technique* was classified as (a) rubbing movement, (b) vertical movement, (c) piano fingers, or (d) other. Rubbing movement was defined as repetitive movements in a circular motion or pushing the fingers back and forth or right to left in a repetitive motion. Vertical movement was defined as pushing the fingertips or pads into and out of the breast tissue in a repetitive motion. Piano fingers were defined as the use of individual fingers, in series, to "march" across the breast tissue in a repetitive fashion. *Search pattern* and *search technique* were coded separately.

4. Sensor Data: MATLAB (R2013b, The MathWorks, Inc., Natick, MA) was used to extract the following sensor data variables: (a) CBE time and (b) average force applied during the examination. CBE time was defined as the time during which the force was above 1 N. Average force was calculated based on the force captured during CBE time.

Data Analysis

Interrater reliability for the video classification of *search pattern* and *search technique* was assessed using a Cohen's Kappa (κ). Consistency in participant *search pattern* and *search technique* across each model was assessed using a Cronbach's Alpha (α). We used a generalized estimation equation to assess the relationship of CBE search pattern and technique with accuracy. Because the breast model was a repeated measure, we evaluated the 4 CBE variables (*search pattern, search technique, palpation force*, and *examination time*) and 6 demographic variables (*gender, years in practice, specialty, exams per week, teaching experience*, and *experience using simulated models*) by participant cluster. Data were stored in a REDCap database.[26] Parametric statistics were performed using IBM SPSS statistics version 22 (IBM Corp., Armonk, NY). A P value less than 0.05 was considered statistically significant.

RESULTS

Demographics and Inclusion Criteria

When evaluating participation rates, we found that 99% of participants (217/219) completed 2 of 2 models and 89% (199/224) completed 4 of 4 models. Five hundred fifty-three participants volunteered to participate in the study. Nonphysicians, residents, and students were excluded (n = 95 participants) as well as physicians not in the fields of surgery, family practice, and obstetrics and gynecology (OB/GYN) (n = 15 participants), leaving a total of 443 participants who performed a total 1296 CBEs. CBEs that were missing video or sensor data (n = 69 CBEs) or had incomplete clinical documentation (n = 76 CBEs) were excluded. In addition, examinations that were classified as "other" for search pattern (n = 14 CBEs) were excluded due to low sample size. There were no examinations in the "other" category for search technique. After all exclusions, 1137 CBEs were included in the final analysis of 443 participants. Analysis of demographic data for the 443 participants showed that 58.7% were female; mean years in practice was 15.6 and specialty breakdown included Family Practitioners (N = 196), Surgeons (N = 123) and Obstetrics/Gynecology (N = 124).[27,29]

CBE Accuracy by Clinical Presentation of Each Breast Model

For model A (2 cm × 2 cm superficial spherical mass), accuracy was 99.6% (N = 283/284). For model B (2 cm × 1 cm superficial spherical mass), accuracy was 89.7% (N = 243/271). For model C (2 cm hard clay mass on chest wall), accuracy was 75.2% (N = 236/314). For model D (2 cm silicon mass near chest wall), accuracy was 60.4% (N = 162/268).

Video Analysis of CBE Skills

Video classification for *search pattern* and *search technique* revealed interrater reliabilities of (k = 0.88) and (k = 0.79), respectively. Analysis of *search pattern* revealed the majority of participants used a circular search pattern when performing the CBE (64%). Others used either radial (19%) or linear (17%), Video #1 http://links.lww.com/SLA/B120. Participants showed moderate-to-high consistency in their *search patterns* across all models (α = 0.79). Analysis of *search technique* revealed the majority of participants used a vertical movement technique (51%). Rubbing movement (31%) was the second most common, followed by piano fingers (18%), Video #2 http://links.lww.com/SLA/B121. Participants showed high consistency in their *search techniques* across all models (α = 0.92). Table 1 shows the distribution of participants' *search technique* by clinical specialty and Table 2 shows the distribution of participants' *search pattern* by clinical specialty. All specialties used each of the aforementioned *search techniques* and *search patterns*.

Factors Associated With Accuracy

Given the high accuracy rates for models A and B, in-depth analyses of factors related to accuracy were only performed using models C and D. These results showed that the following factors had significant effects on accuracy: (A) search technique (*rubbing movement*—OR = 3.06, *P* = 0.002; *vertical movement*—OR = 1.30, *P* = 0.409; *piano fingers*—OR = 1.00); (B) specialty (*surgery*—OR = 7.24, *P* < 0.001; *family practice*—OR = 1.63, *P* < 0.065; OB/GYN—OR = 1.00); and (C) force (OR = 1.15, *P* < 0.001). Piano fingers had the highest failure rate for models C and D (46.5%–46/99) combined.

To further assess the validity of our results we repeated our analyses on model C only, as the surgeons did not examine model D. The results once again confirmed that search technique, specialty, and force are significant predictors of accuracy (Table 3). In addition, it is noted that rubbing movement was almost 4 times more likely to yield an accurate assessment (OR 3.81, *P* < 0.001) compared with vertical movement and piano fingers. When assessing the relationship between search technique, force, and accuracy, we noted that piano fingers have both lower accuracy and a lower force distribution (Fig. 2).

DISCUSSION

Prior assessments of CBE utility were based on the assumption of physician competency. Our findings show that specific techniques that may have been handed down by tradition and taught as part of the routine clinical training afford different levels of accuracy. Although the United States Preventive Task Force has repeatedly declared insufficient evidence regarding usefulness of the CBE for screening,[2] we believe that future evaluations should consider CBE technique as an independent variable that impacts CBE accuracy. More importantly, the use of the CBE is not limited to screening. It is the first step in evaluating symptomatic breast patients[28] and has shown to improve accuracy in preoperative assessment of breast cancer.[29] Finally, the CBE is an important part of routine breast cancer follow-up after primary treatment.[30] Although the CBE will still be widely used by physicians, a decrease in the use of CBE for screening will also reduce medical students' opportunity to master this skill. Sensor-enabled simulators and objective tools classifying search technique can help fill in this gap.

Our goal was to find new ways to provide health care professionals improved feedback on clinical skills. To achieve this goal, we explored the potential value added by incorporating video classification of CBE hand movements into a sensor-based model for clinical performance testing.[4,31] Newly proposed nomenclature helped to define 3 *search techniques* for the CBE: *rubbing movement, vertical movement*, and *piano fingers*. Analysis revealed that the search technique used significantly and independently affected CBE accuracy ($P < 0.001$). Moreover, practitioners who use the piano fingers search technique were noted to have unusually high rates of missed lesions (46.5%). These findings have clinical relevance for patients and physicians. Both groups should be informed regarding the potential for suboptimal and inaccurate outcomes when using specific CBE techniques. The newly defined *search techniques* (*rubbing movement, vertical movement*, and *piano fingers*) are easily discernable via direct observation or video (Video #2 http://links.lww.com/SLA/B121).

In addition to reporting, a newly defined component of the CBE (*search technique*), this study also revealed persistent variations in CBE *search pattern*.[19,32–34] Despite widely accepted recommendations for the linear search pattern,[15–17] the most commonly used search pattern in our study was the circular pattern. Moreover, our results did not show a significant relationship between search pattern and accuracy, thus challenging these recommendations.

The use of sensor technology and video classification to characterize and model CBE skills represents a paradigm shift in our ability to evaluate CBE skills. Our results support the development and implementation of competency standards for CBE skills. Evaluating competency in hands-on skills may improve training and help bridge the gap between current CBE teaching methods and effective, evidence-based performance.[27,34–36] This work also has implications for other clinical skills assessments and sheds light on potential directions for other research using sensors to characterize clinical examination and procedural skills.[19,21]

Study limitations relate to the use of simulated models and data collection conditions. Regarding the use of simulation, our findings show a high consistency in participant search pattern and technique during the CBE, suggesting transferability in technique from live patients to simulated models. However, there may be variations in the amount of force used in real versus simulated patients. Our ability to fabricate a range of difficulties in clinical presentation and achieve measurable changes in accuracy provides additional evidence for the validity of our models.[19,37] Study condition limitations involve the use of a convenience sample of physicians at national meetings. Our target population was surgeons, family practitioners and OB/GYN physicians who perform CBEs. However, our goal was to focus on the potential value added by using video for assessing CBE technique. As such, our group of practicing physicians with variations in gender, specialty, years in practice, and examinations per week provides a heterogeneous sample to assess the utility of video classification in characterizing unsuccessful CBE techniques. In assessing additional threats to validity, we note that our clinical scenario was scripted in such a way that participants were biased toward positive detection. This may have led some participants to conduct extensive explorations, potentially inflating the detection rate accuracy. However, those who failed to identify the lesions under these circumstances provide highly useful data regarding unsuccessful techniques.

We have discovered and defined a CBE search technique (piano fingers technique) that is associated with an unusually high rate of missed lesions. In our prior work, using sensors, we also showed the importance of palpation force in CBE accuracy.[4] These combined results may facilitate diagnostic accuracy by increasing physical examination competency through enhanced feedback.[31] As advancements in medical and engineering technology continue to move forward, the medical profession must strive to adopt new approaches and strategies to improve patient care. Computer-based modeling and assessment of CBE technique, and other hands-on clinical skills, can allow for better training, more effective feedback and remediation, and improved performance.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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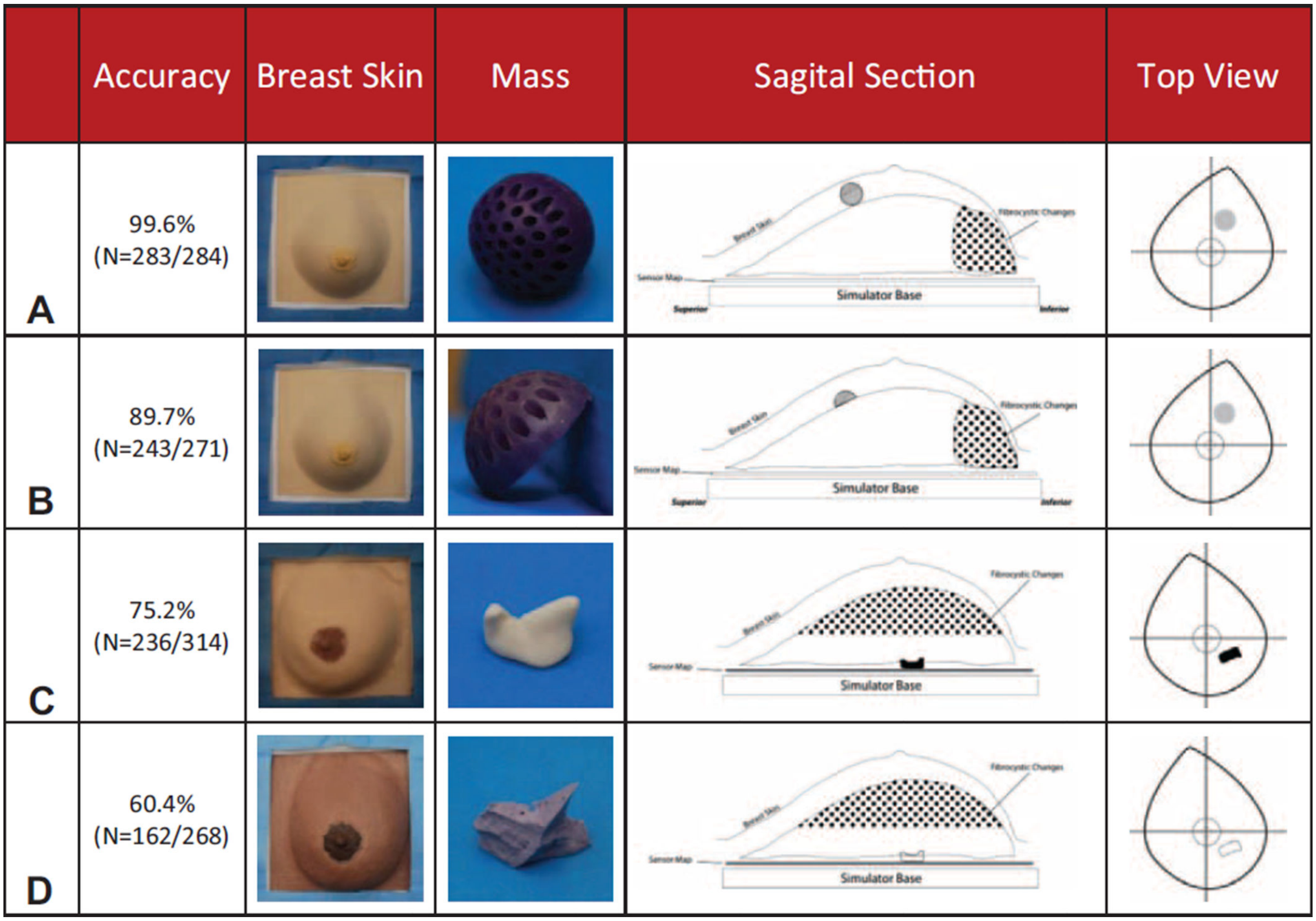

FIGURE 1.

Illustration of model composition and setup of breast simulators. The mass in simulator A was a soft, rubbery 2 × 2 cm sphere. For simulator B, the sphere was cut in half and accuracy decreased 10%. For simulator C, the mass was an oddly shaped, hard clay mold. For simulator D, the mass was shaped the same as the mass in simulator C, but was made from a firm silicone material. Accuracy decreased by 14.8%.

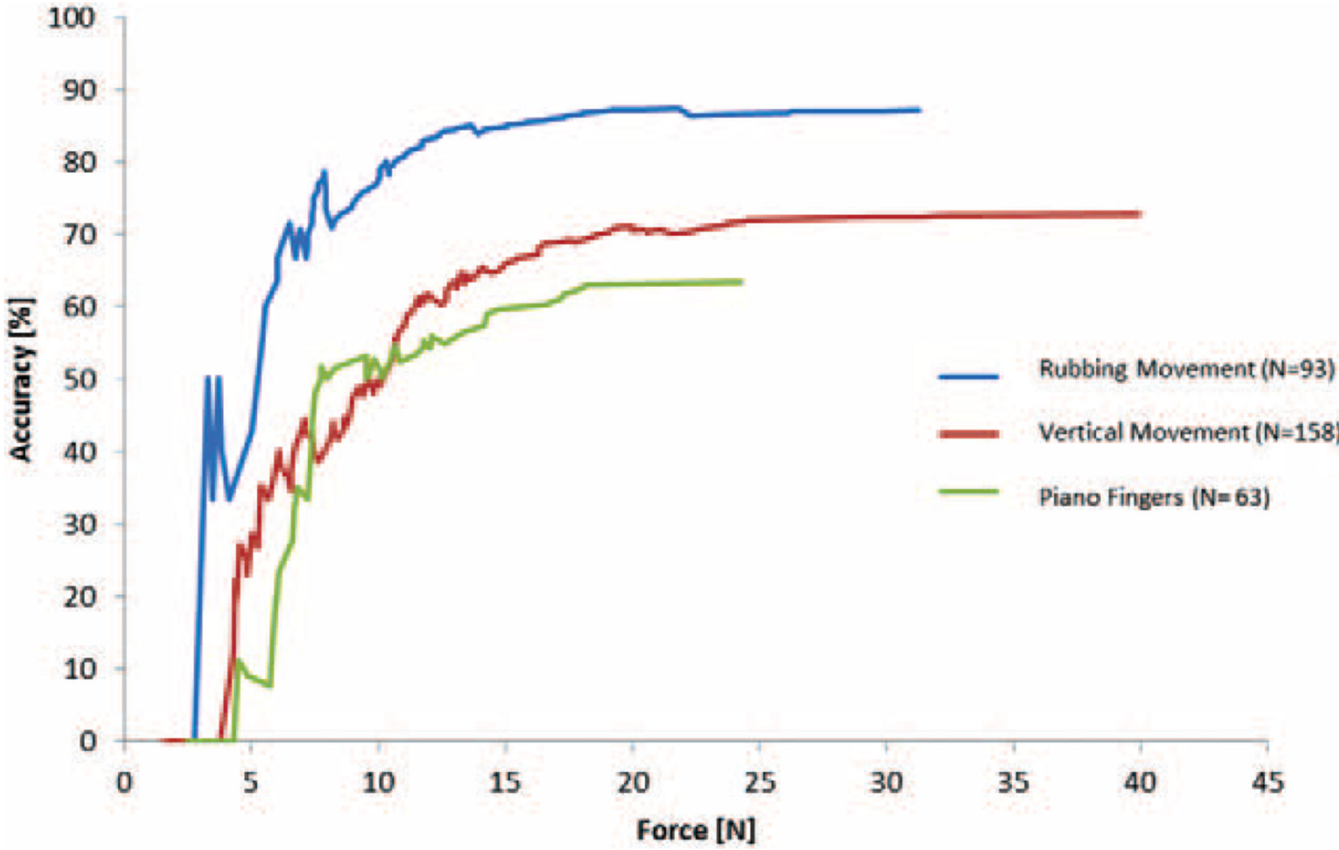

FIGURE 2.

Relationship between force, accuracy and search technique (rubbing movement, vertical movement and piano fingers) for model C*.

TABLE 1

Search Technique by Clinical Specialty

	Search Techniques		
	Rubbing Movement	**Vertical Movement**	**Piano Fingers**
Surgeons			
Frequency	29.2% (56/192)	45.8% (88/192)	25.0% (48/192)
Average force, N	12.02 (0.67)	12.60 (0.71)	9.22 (0.74)
Family practitioners			
Frequency	36.1% (189/524)	54.6% (286/524)	9.3% (49/524)
Average force, N	12.31 (1.04)	11.95 (0.85)	13.93 (2.09)
OB/GYN physicians			
Frequency	25.9% (109/421)	49.4% (208/421)	24.7% (104/421)
Average force, N	10.27 (1.25)	13.88 (0.98)	8.24 (1.28)

TABLE 2

Search Pattern by Clinical Specialty

	Search Pattern		
	Circular	**Radial**	**Linear**
Surgeons			
Frequency	47.9% (92/192)	33.3% (64/192)	18.7% (36/192)
Average force, N	12.17 (0.65)	11.02 (0.77)	11.10 (1.06)
Family practitioners			
Frequency	68.3% (358/524)	17.7% (93/524)	13.9% (73/524)
Average force, N	12.11 (0.69)	13.66 (1.62)	9.28 (2.76)
OB/GYN			
Frequency	66.5% (280/421)	12.6% (53/421)	20.9% (88/421)
Average force, N	11.84 (0.90)	11.11 (0.96)	10.92 (1.19)

TABLE 3

Generalized Estimation Equation Model Predicting the Likelihood of Successfully Identifying a Deep Mass (Model C) Using Demographics, Sensor, and Video Data

	Mean (SD) or Frequency (%)				
Independent Variable	**Success**	**Failure**	**Odds Ratio**	**95% CI**	***P***
Average force, N	12.89 (5.85)	8.38 (4.69)	1.25	1.13–1.38	<0.001
Search technique					
Rubbing movement	81 (87.1%)	12 (12.9%)	3.81	1.25–11.59	0.018
Vertical movement	115 (72.8%)	43 (27.2%)	0.95	0.38–2.38	0.906
Piano fingers	40 (63.5%)	23 (36.5%)	1.00		
Search pattern					
Circular	142 (72.4%)	54 (27.6%)	0.72	0.24–2.11	0.543
Radial	58 (82.9%)	12 (17.1%)	0.99	0.32–3.09	0.986
Linear	36 (75.0%)	12 (25.8%)	1.00		
CBE time, s	65.24 (38.98)	54.55 (28.92)	1.01	0.99–1.02	0.252
Gender					
Female	143 (79.0%)	38 (21.0%)	1.00		
Male	85 (69.7%)	37 (30.3%)	0.53	0.26–1.06	0.071
Years in practice	15.51 (10.57)	16.82 (10.70)	0.98	0.95–1.02	0.256
Clinical specialty					
Surgery	92 (86.0%)	15 (14.0%)	7.79	3.27–18.58	<0.001
Family practice	83 (87.4%)	12 (12.6%)	6.07	2.50–14.76	<0.001
OB/GYN	61 (54.5%)	51 (45.5%)	1.00		
Examinations per week					
0–5	49 (80.3%)	12 (19.7%)	1.00		
6–10	45 (81.8%)	10 (18.2%)	0.93	0.26–3.35	0.914
11–20	44 (65.7%)	23 (34.3%)	0.52	0.18–1.56	0.246
>20	94 (74.7%)	33 (26.0%)	0.50	0.16–1.58	0.240
Teach CBE					
No	98 (76.6%)	30 (23.4%)	1.21	0.62–2.39	0.577
Yes	130 (73.4%)	47 (26.6%)	1.00		

Independent Variable	Mean (SD) or Frequency (%) Success	Failure	Odds Ratio	95% CI	*P*
Experience with models					
No	136 (72.3%)	52 (27.7%)	0.64	0.30–3.09	0.264
Yes	90 (78.9%)	24 (21.1%)	1.00		

CI indicates confidence interval; SD, standard deviation.