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TOPIC:
PRACTICE POLICY AND QUALITY INITIATIVES – USING LEAN PRINCIPLES TO IMPROVE SCREENING MAMMOGRAPHY WORKFLOW

Approved for one (1) Clinical Continuing Educational Units
Practice Policy and Quality Initiatives

Using Lean Principles to Improve Screening Mammography Workflow

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The “lean” approach is a quality improvement method that focuses on maximizing activities that are valued by the customer and eliminating waste that impedes efficiency in the workplace. The unique philosophy of the lean approach encourages all members of the team to be directly involved in identifying areas of waste and generating solutions to eliminate them. When the breast imaging section at the authors’ institution became part of a multispecialty breast care center, the result was escalating examination volumes, more complex cases, and overall increased demand on radiologists’ time. After several unsuccessful attempts to improve the efficiency of the section, including evaluation by outside consultants, the decision was made to embark on a comprehensive quality improvement program using the lean approach. A team of radiologists, technologists, file room personnel, information technology (IT) representatives, and administrators from the breast imaging section met twice a month to learn about lean principles and how to apply them to screening mammography workflows. Sources of inefficiency (waste) were identified, and potential solutions were generated. Multiple trials were performed to test these solutions. Throughout the process, all team members were engaged in identifying the problems, suggesting solutions, and implementing change. Most of the tested solutions were successful and resulted in decreased patient wait times, improved efficiency for the technologists and radiologists, faster report turnaround, and advances in IT. In addition, staff members were introduced to the lean philosophy and became actively involved in improving their workplace, resulting in a more cohesive section.

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Introduction
When our breast imaging section became part of a multispecialty breast care center, we began facing escalating examination volumes, more complex cases, and an overall increase in demand on the radiologists’ time. Over the years, four outside consultants were contracted to evaluate the inefficiencies of the department and offer solutions. However, each of these “solutions” had only limited success, since they were not individualized to the breast imaging section and personnel and did not fully engage the radiologists and technologists as the agents of change. Therefore, the decision was made to embark on a comprehensive quality improvement program using the “lean” approach.

What Is the Lean Approach?
The lean approach is a systematic approach to continuous improvement in performance that was originally developed in the automotive industry and codified in the Toyota Production System (1). The lean approach strives to eliminate all forms of waste within a given process, so that fewer resources are required and less cost is generated in achieving equal or greater levels of productivity. The fundamental principles of the lean approach are listed in Table 1 (2). The end goals of the lean approach are improved productivity, decreased cost, and increased customer satisfaction. In the process, the work environment becomes better organized, safer, and more efficient.

The lean approach is more than just a set of written principles for quality improvement; it is a process improvement philosophy that seeks continuous change in how the workers within an organization think and act, thereby transforming how the entire organization approaches work and management (1,3). With this unique philosophy, all members of a team are empowered by being directly involved in identifying problems, generating solutions, and implementing new plans, thus creating a culture change (4). This “lean transformation” is what sets the lean approach apart from other quality improvement methods.

In recent years, the lean approach has also been applied to radiology and other areas of healthcare (1,3,5). Various radiology departments have used the lean approach to evaluate magnetic resonance imaging examination times (6), evaluate mammography workflow (4), and decrease wait times for patients who undergo peripherally inserted central catheter placement (7). Other hospital departments have used lean principles to manage patient throughput (8), increase appropriate antibiotic therapy (9), and improve workflow (5). Whereas the automotive industry focuses on the customer and automobile production, the healthcare industry focuses on the patient, and all potential solutions are generated with the patient’s satisfaction in mind. In a breast imaging department, lean principles can be applied to decrease patient wait times, improve staff productivity, and standardize workflows, with the overall goal of improved patient and staff satisfaction.

In this article, we describe the principles and tools of the lean approach and discuss their application for improved workflows in a breast imaging center.

Lean Methodology
A team consisting of radiologists (faculty, fellows, and residents), technologists, file room personnel, information technology (IT) representatives, and administrators from the breast imaging section met twice a month from February 2012 to January 2013 to learn about the lean approach and how to apply it to the section. The members of the “lean team” were selected by the chief of the breast imaging section. Key staff members from all parts of the

<table>
<thead>
<tr>
<th>Table 1: Fundamental Principles of the Lean Approach</th>
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<tbody>
<tr>
<td>All staff equally involved and respected</td>
</tr>
<tr>
<td>“Going to the gemba”: observing and analyzing processes where they occur</td>
</tr>
<tr>
<td>Elimination of waste in all forms</td>
</tr>
<tr>
<td>Standardization of work to minimize variations</td>
</tr>
<tr>
<td>Improvement in the flow of all processes within the system</td>
</tr>
<tr>
<td>Use of visual cues for communication</td>
</tr>
<tr>
<td>Adding value for the customer</td>
</tr>
<tr>
<td>Application of lean tools for collection and analysis of data to improve processes and sustain change</td>
</tr>
</tbody>
</table>

Note.—Adapted, with permission, from reference 2.
section were included to ensure proper representation. These individuals included two staff radiologists, one breast imaging fellow, one radiology resident, the lead technologist, an additional technologist, two file room staff members, the lead scheduler, the manager of the breast care center, the director of radiology, and a representative from Clinical Imaging Services. The meetings were facilitated by an engineer with training in the lean approach and experience in applying lean principles to healthcare.

The first meeting each month focused on learning lean principles, identifying problems within workflows, brainstorming potential solutions to these problems, and designing trials to test the utility of these solutions. This meeting took place on a Friday during normal working hours (8 AM–5 PM). As a result, the clinical volume, especially the number of diagnostic examinations and procedures, was decreased on these days. The second meeting each month took place on the following Monday during normal working hours and focused on executing the trials and evaluating the resulting data. In the morning, the lean team members and the lean consultants collected the data; in the afternoon, the lean consultants consolidated the data. At the end of this working day (4 PM–5 PM), a report-out was led by the lean consultants, with all members of the section invited. The patient schedule was not adjusted on this day. Screening mammography was chosen as the place to begin because its workflow is the least complicated, affording the opportunity to make early gains while mastering the lean principles. Throughout this transformation, a bottom-up rather than top-down management approach was emphasized (2,7) to encourage all team members to participate in identifying problems, suggesting solutions, and implementing the plans.

**Patient-centered Approach**

The first step in a lean transformation is to identify the customer and define “value” from his or her perspective (10). In our breast imaging section, the patient was established as the primary focus. Activities that the patient would consider valuable were defined (eg, time spent with the physician or technologist). Areas of waste—again, from the patient’s perspective—were also identified (eg, waiting) (11). The goal of the lean approach is to maximize the valued activities while minimizing waste (Fig 1). With this concept at the center of all anticipated changes, the lean team began to learn about the various lean tools and how to use them to improve screening mammo-
Value Stream Map

A value stream map is a tool used to lay out the general steps of a given process or workflow, thereby providing a framework for initiating the lean transformation \((2,3,5,12)\). This technique documents the current flow of information or materials, such as the steps involved in acquiring a screening mammographic study or in generating a final report. The value stream map allows analysis and improvements at each step within a larger context. Each individual change can be viewed within the overall system, allowing a more cohesive transformation and preventing disjointed or suboptimal efforts. The map can also be used as an important backdrop for data collection.

Creating a value stream map requires identification of the steps that add value to the overall workflow \((12)\). The added value could be from the patient’s or the staff’s perspective. Consequently, this tool also helps identify waste, which is defined as anything that utilizes resources but does not add value to the process \((2)\).

Key steps within the screening mammographic examination process are illustrated in Figure 2. Each value-added step represents an activity in the overall experience that the patient cares about. The majority of non-value-added activities or areas of waste within a given system can be identified between these value-added steps. This waste takes up time, resources, or space without providing value to the patient.

Identification of Waste

Waste can fall into one of seven categories: motion, transportation, inventory, waiting, defects, overprocessing, or overproduction \((1,2,5,12)\). Wasted motion is unnecessary movement of patients or staff members, whereas wasted transportation is unnecessary movement of supplies or equipment. The waste of inventory refers to having an inappropriate amount of supplies available, whether too much or too little. The waste of waiting refers to the patient or staff waiting for the next step in a process to occur. Defects are defined as errors or flaws in the system, overprocessing is defined as redundancies that occur in a process, and overproduction is defined as excess work that does not add value to a process \((2)\).

A fundamental lean principle is the direct observation of processes where they occur (going to the gemba) to identify waste \((1,2,5,8)\). As an application of this principle, a “waste walk” was performed within the breast imaging section. During this exercise, team members silently observed normal workflows by shadowing patients from check-in to checkout, technologists from the start to the end of an examination, and physicians as they interpreted screening mammograms and generated reports. Wastes for each process were then categorized as described earlier \((Table 2)\).

5-S Tool

The lean tool known as “5-S” focuses on enhancing visual order and organization in the workplace to optimize efficiency \((1,2,4,5)\). The five components of 5-S all begin with the letter S: sort, straighten, shine, standardize, and sustain \((Table 3)\). This tool is not a one-time process but an ongoing effort to improve and maintain workplace organization.

To implement 5-S within the section, the lean team visited the patient examination rooms, procedure rooms, supply room, and radiologist reading room. Items that were stored in excess or were not in an easily accessible location were identified.
Unnecessary supplies and clutter were removed. The remaining supplies were then organized based on their utility and frequency of use. For example, all biopsy needles and marker clips were stored in the same cabinet, and all postbiopsy bandaging supplies were placed in the same drawer. Supplies used only infrequently were moved out of the procedure rooms and into the storage area, which was cleaned, organized, and labeled. The cabinets and drawers in all examination and procedure rooms were labeled with their contents to limit the amount of time staff members spent searching for

### Table 2

**Categories of Waste Observed in the Breast Imaging Department**

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
<th>Examples</th>
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</thead>
<tbody>
<tr>
<td>Motion</td>
<td>Unnecessary movement of patients or staff</td>
<td>Technologist searching for available examination rooms; staff searching for materials, attempting to locate physicians or other staff, or walking to collect printed materials</td>
</tr>
<tr>
<td>Transportation</td>
<td>Unnecessary movement of supplies or equipment</td>
<td>Moving film jackets to the reading room to be read, hanging hard-copy images, returning and filing a film jacket once a study has been read</td>
</tr>
<tr>
<td>Inventory</td>
<td>Inappropriate amount of supplies (too much or too little)</td>
<td>Not all necessary forms available at each reading room workstation, staff leaving examination room to search for supplies, some rarely used supplies kept in examination room</td>
</tr>
<tr>
<td>Waiting</td>
<td>Delays for patients or staff</td>
<td>Patient waiting in lobby after check-in or waiting in changing room or waiting area while technologist prepares examination room, technologist waiting for patient to finish changing, resident waiting for batch of studies to be brought to reading room or waiting to staff cases with attending physician</td>
</tr>
<tr>
<td>Defects</td>
<td>Errors or flaws in the system</td>
<td>Screening patient requires additional diagnostic imaging or procedures that were not scheduled, tedious computer system with multiple technical glitches</td>
</tr>
<tr>
<td>Overprocessing</td>
<td>Redundancies caused by unclear definition of what needs to be done and by whom</td>
<td>Technologist having patient move to a different room due to lack of necessary equipment, multiple computer systems and log-ons required by the technologist to complete one study, radiologist transferring digital comparison images from PACS to workstation</td>
</tr>
<tr>
<td>Overproduction</td>
<td>Excess work that does not add value</td>
<td>Technologists and radiologists maintaining patient log on clipboard</td>
</tr>
</tbody>
</table>

### Table 3

**Components of 5-S and Their Definitions**

<table>
<thead>
<tr>
<th>Component</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sort</td>
<td>Retain necessary items and remove unnecessary items</td>
</tr>
<tr>
<td>Straighten</td>
<td>Organize and arrange items in easily accessible locations</td>
</tr>
<tr>
<td>Shine</td>
<td>Keep working areas and equipment clean and well maintained</td>
</tr>
<tr>
<td>Standardize</td>
<td>Design a system to maintain the implemented order</td>
</tr>
<tr>
<td>Sustain</td>
<td>Perform continuous upkeep to maintain changes of the previous components</td>
</tr>
</tbody>
</table>

Note.—Adapted, with permission, from reference 2.
supplies (Fig 3). In the radiologist reading room, all necessary forms (eg, those needed for screening mammography “recalls”) were made accessible at every reading workstation. Initially, these changes were attempted during normal working hours without adjusting the schedule; however, this was found to be disruptive to the other staff members, who did not understand what was being done and why these changes were being made. After properly educating the other staff members about 5-S and asking for their feedback about the proper locations of supplies, we later implemented these changes during a lunch hour.

**Process Map**

A process map begins with the value stream map and breaks each value-added step down into smaller, more detailed steps (2). This often-lengthy map defines exactly how and by whom each step is completed. Clearly defining each step within a process allows increased awareness of the overall process, identification of potential bottlenecks in workflow, and insight into additional potential areas of waste (Fig 4).

**Visual Communication**

Visual communication is a key component of the lean transformation. This principle dictates that valuable information be displayed in a place where it is visible to all staff members (1,2). There are numerous benefits of visual communication that are recognized in the lean approach. Fundamentally, a visual communication tool should be visible from long distances to save wasted motion for all staff. This information is shared with everyone, regardless of their role within the system, allowing people to make real-time adjustments to achieve the desired outcome. The environment becomes one of self-service in which staff members can access the information they need at any given moment to make a decision without the need for verbal communication that might interrupt another person’s workflow. Finally, everyone on the team becomes aware of how their role fits into the overall process and can therefore find meaning in their actions. Incorporating visual communication into the breast imaging section required open discussion and feedback among all staff members. Various visual communication solutions were tested in the section and are discussed later in this article.

**Application of Lean Tools in Our Practice**

Once the team had become familiar with the basic lean tools, we began applying them to our practice. Each component of the screening mammography workflow was scrutinized with process maps to identify additional areas of waste. Separate process maps were created for the technologist workflow, the radiologist reporting workflow, and the workflow for generating finalized reports and mailing patient lay letters. The team then worked together to generate potential solutions to decrease or eliminate the identified areas of waste. A trial of each solution was created and executed to test its utility. A summary of the implemented trials is shown in Table 4.
Figure 4. (a) Schematic illustrates how a process map is created by enumerating individual steps within the larger context of the value stream map. (b) Process map illustrates the technologist workflow for screening mammography. (Fig 4 adapted and reprinted, with permission, from FlowOne Lean Consulting, Menomonee Falls, Wis.)

<table>
<thead>
<tr>
<th>Workflow Component</th>
<th>Trial</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technologist workflow</td>
<td>Lead technologist</td>
<td>One technologist (named lead technologist for the day) watches for checked-in patients and assigns patients to next available technologist and examination room</td>
</tr>
<tr>
<td></td>
<td>Portable electronic device</td>
<td>Electronic tablet and smart phone used to verify patient identifiers</td>
</tr>
<tr>
<td></td>
<td>Patient wait time</td>
<td>Aide (rather than technologist) greets patient and escorts her to changing room and adjacent waiting area; patients observed from check-in to checkout, visit length (including wait times) recorded</td>
</tr>
<tr>
<td></td>
<td>Visual communication</td>
<td>White boards created to track the locations of patients, technologists, and radiologists within the department</td>
</tr>
<tr>
<td>Radiologist reporting</td>
<td>Electronic work list</td>
<td>Paper workflow converted to an electronic reading work list</td>
</tr>
<tr>
<td></td>
<td>Digitizer</td>
<td>Hard-copy comparison images digitized before patient’s appointment</td>
</tr>
<tr>
<td></td>
<td>Redefining roles</td>
<td>Examinations previewed by assistant to ensure everything is available on the workstation for the radiologist to read</td>
</tr>
<tr>
<td></td>
<td>Evaluation of IT systems</td>
<td>Four separate IT systems and their interfaces investigated to improve efficiency</td>
</tr>
<tr>
<td>Generating reports and mailing results letters</td>
<td>Printer relocation</td>
<td>Printer moved to assistant’s office</td>
</tr>
<tr>
<td></td>
<td>Report printing</td>
<td>Errors in printing process observed, revision of automated patient results letters initiated</td>
</tr>
<tr>
<td></td>
<td>Lay letter mailing</td>
<td>Results letters mailed earlier in the day, making results available to patients 1 day sooner</td>
</tr>
</tbody>
</table>
Lead Technologist Trial
Before the lead technologist trial, when a patient checked in at the front desk for her examination, a paper requisition form would print out in the technologist work area. All technologists would listen for the printer to notify them that a patient had arrived. A technologist sitting far from the printer might not hear the requisition form being printed out, or several technologists might hear the printer and walk over to see which patient had arrived. Then, the technologists would decide who was going to perform the examination. In an attempt to minimize this wasted motion and overprocessing, a workflow was devised in which one technologist was designated as the lead technologist for the day. This technologist sat near the printer and watched for requisition printouts (indicating newly arrived patients). She would then assign each patient to the next available technologist.

Portable Electronic Device Trial
Walking to the printer to retrieve the requisition form is a waste of motion for the technologists, not to mention a waste of paper. To address these areas of waste, a paperless workflow using portable electronic devices was tested. Instead of relying on the paper requisition form, the technologists carried an electronic mobile device with them to verify patient information. An electronic tablet and a smart phone, both existing property of the IT section, were tested for this purpose.

Patient Wait Time Trial
Before the application of lean principles, the technologist performing the examination would greet the patient in the waiting room and escort her to the changing room. While the patient was changing, the technologist would search for an open mammography room and prepare it for the patient. This often led to the patient having to wait for the technologist or vice versa. A patient wait time trial was created in which an aide would greet the patient and escort her to the changing room and adjacent waiting area. This allowed time for the technologist to prepare the mammography room and then greet the patient in the waiting area, reducing unnecessary motion and wait time. The aide was not an additional hire for the department; the duties of the aide were added to those of an existing file room assistant. Her computer was moved to the technologist work area so that she could complete both her new aide duties and her existing file room duties at the same time. Patient wait times and overall visit lengths within the department before and during this trial were recorded. Statistical analysis of the changes in mean patient wait time and mean visit length was performed using the two-tailed t test.

Visual Communication Trial
Two large magnetic dry erase boards (white boards) were created to improve communication and decrease waste in the breast imaging section (Fig 5). During the waste walk, technologists were observed searching for open examination rooms. To eliminate this waste of time and motion, a technologist white board was created to track examination room availability. Also during the waste walk, technologists were observed searching three reading areas for a radiologist to check a diagnostic mammographic study. Although this action was not in itself part of the screening workflow, it frequently led to interruption of the radiologist’s review of screening mammographic images, disrupting report generation and resident teaching. Thus, a physician white board was created to display the location of the radiologists at any given time.

On the technologist white board (Fig 5a), the position of the magnets indicates which examination rooms are in use, the location of each patient, and which technologist is performing each examination. The board includes a column that denotes examination start time, allowing the lead technologist to anticipate when an examination room might become available. Additional information (eg, whether a patient will require more than one technologist to complete her examination, whether a room is unavailable due to equipment repair or maintenance) can be shared in the “Comments” column. A smaller batting order–type dry erase board was created to keep track of which technologists were working and who was next in line to perform an examination (Fig 5b).

The physician white board (Fig 5c) shows the names and locations of the faculty radiologists who are in the department for the day. It also displays the location of the fellow, residents, and nurses. It is each radiologist’s responsibility to move his or her magnet upon changing location—for example, when moving from the screening workroom to a workstation in the main mammography reading area. In addition, the physician...
white board lists all procedures and meetings for the day so that others can anticipate when a radiologist will be unavailable.

The layout and content of each of these white boards has evolved since their initial implementation. Each version of the white boards was tested for a month. Feedback and suggestions were collected from all staff members, not just those on the lean team. Improvements to the boards were made on the basis of these suggestions.

**Electronic Work List Trial**

Previously, upon completing a patient’s screening examination, the technologist would place the paper requisition form and any previously obtained hard-copy images in a film jacket and place this jacket in a slot in the technologist work area. An assistant would wait for a batch of completed examinations to accumulate and then take them to the screening reading room. She would then write all of the patients’ names on a clipboard and note whether the comparison images were digital or hard-copy images. Hard-copy comparison images would be hung on a film alternator, and the panel number would be indicated on the clipboard next to the patient’s name. The resident and the faculty radiologist would then locate each patient listed on the clipboard on the reading work list in the mammography reporting system and open the examination. (The reading work list in the reporting system is electronically linked with the image display workstation.) Once the images had been read, the patient’s name was crossed off the clipboard and the film jackets were moved to a cart for filing.
To combat the wasted motion, wasted transportation, and overprocessing in this reading workflow, an electronic work list was implemented. Screening mammographic studies with no comparison images or with only digital comparison images were assigned a specific status ("AutoTrack") on the reading work list by the technologist upon completion of the examination. This label indicated that the study was available for immediate review without requiring a paper requisition form, a film jacket, or the clipboard. This process allowed sorting of the studies that were ready to be read as indicated on the reporting system and eliminated time wasted by the radiologist in searching for the patient’s name on the reading work list. The average read time per case for both the resident and the staff radiologist before and after this trial was recorded. Statistical analysis of the difference in average read time was performed using the two-tailed t test.

**Digitizer Trial**

The wasted time, motion, and transportation caused by hanging hard-copy comparison images on an alternator were eliminated when the section purchased a digitizer. In anticipation of upcoming appointments for screening mammography, an aide digitized previously obtained hard-copy images before the patient arrived. If the patient arrived with hard-copy images from an outside institution, these images were digitized before the examination was made available for the radiologist to read. Once the images were digitized and sent to the mammography workstation, the study was assigned AutoTrack status in the mammography reporting system, alerting the radiologist that it was ready to be interpreted.

**Redefining Roles Trial**

Because of limited local memory on the image display workstations, studies awaiting receipt of comparison images from an outside institution would often “drop off” the workstation before they were interpreted. In such cases, the radiologist would have to query the picture archiving and communication system (PACS) for the study and transfer the images to the reading workstation, a waste of the radiologist’s read time. A new task for the assistant was tested in which she previewed the examinations and ensured that all necessary studies were available on the workstation before listing the examination on the reporting work list as ready to review. However, it soon became apparent that this was only a temporary solution to a much larger problem with the current IT system.

**Evaluation of IT Systems**

The breast imaging section uses four separate systems for mammographic image interpretation. The mammography reporting system is distinct from the hospital electronic medical record, and the image display system is separate from the hospital PACS, often resulting in problematic system interfaces. The radiologist must navigate between these separate systems to access all the images and information necessary for interpretation of a study. For example, only limited clinical information is available in the mammography reporting system, requiring the radiologist to access the electronic medical record with a separate log-in to obtain background clinical information. In addition, several flaws with the current mammography reporting system have been identified, as report creation requires significant self-editing by the radiologist.

As it became evident that the technology systems were crucial contributors to the inefficiencies of the section, major investigations of the mammographic image display system and mammography reporting system were launched. In conjunction with specialists from the clinical imaging department, demonstrations of mammography workstations from two different vendors (an upgraded version of the current mammographic image display system and a mammography module in the department-wide PACS) were organized. Similar demonstrations of reporting systems are underway.

**Printer Relocation Trial**

Once reports were completed by the radiologists, an assistant would print a list of completed studies and their accompanying reports and patient lay letters. The assistant did not have a printer in her office, which required her to walk to the technologist work area to retrieve the printouts. To eliminate this wasted motion, a printer was simply moved to the assistant’s office.
address, incorrect ordering physician information, or a missing patient lay letter. The assistant may also need to edit an individual patient’s lay letter as directed by the radiologist if the message to be communicated to the patient is not clearly stated in the lay letter templates.

This printing and editing process was directly observed and data were collected as part of a trial to determine the types of errors that occurred and their frequency of occurrence. The need to customize the wording of an individual patient’s lay letter was found to be the most common problem encountered by the assistant. The data from this trial gave rise to a project to revise the patient lay letters. Also, the IT department and representatives of the electronic medical record and mammography reporting system were made aware of the demographic glitches and are in the process of resolving these issues.

Lay Letter Mailing Trial
Previously, all patient lay letters were folded and mailed at the end of each day. With this workflow, the lay letter for a report completed in the evening would not be mailed until the following afternoon. To reduce patient wait time, a lay letter mailing trial was proposed in which all lay letters were folded and mailed earlier in the day, allowing patients whose reports were completed in the evening and early morning to receive their results 1 day sooner.

Results
Overall, this project has resulted in decreased patient wait times, improved efficiency for the radiologists and technologists, faster report turnaround, advances in IT, and several additional benefits.

Multiple factors contributed to overall improved patient wait times within the department. On average, 46 patients undergo screening mammography each day in our department. Before the patient wait time trial was implemented, the average wait time for a screening mammography patient was 11.1 minutes. After the trial, the average wait time was just 3.3 minutes (Table 5).

Although this change in average patient wait time is not statistically significant, this could be due to the small sample size. Nevertheless, overall patient wait time decreased by 70%, and the median patient visit length decreased from 32.5 to 25 minutes. This decrease in visit length ensured that the schedule was adhered to so that patients were not kept waiting and the technologists were able to go to lunch on time. The implementation of the technologist white board as part of the visual communication trial also allowed the technologists to ensure efficient care by monitoring the whereabouts and wait times of patients in the department and by making real-time adjustments if a bottleneck was encountered.

Many of the trials improved the efficiency of the radiologists. With the implementation of the electronic work list trial and redefining roles trial, faculty radiologist read times for screening mammography decreased from 4.8 minutes per case in February 2012 to 2.9 minutes per case in March 2012. Average resident read times did not change significantly because different residents or fellows with varying degrees of experience were observed each time. Statistical analysis of the March 2012 data could not be performed because the raw data were purged. However, resident-fellow and staff read times were reevaluated 1 year later in April 2013 and yielded consistent results (Table 6). This increase in efficiency has provided the radiologists with more time to teach fellows, residents, and medical students and has enabled them to devote more time to other modalities in breast imaging. In addition, a faster report turnaround time for our patients was achieved, since the resident or radiologist no longer has to wait for the assistant to bring a batch of paper requisition forms to the reading room to read the examinations. The radiologist simply looks at the reporting system work list and reads examinations as soon as they are assigned AutoTrack status. Implementation of the digitizer trial has also

<table>
<thead>
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<th>Table 5</th>
<th>Results of Patient Wait Time Trial</th>
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<tbody>
<tr>
<td></td>
<td>Pretrial (n = 10)</td>
</tr>
<tr>
<td>Time Spent by Patient</td>
<td>Average</td>
</tr>
<tr>
<td>Wait time (min)</td>
<td>11.1</td>
</tr>
<tr>
<td>Total visit length (min)</td>
<td>33.7</td>
</tr>
</tbody>
</table>
allowed examinations to be read without waiting for an assistant to hang the previously obtained hard-copy images on an alternator in the reading room. In addition, the digitizer trial led to a more seamless comparison with prior studies and a tidier workspace for the radiologists, since there was no longer a pile of film jackets containing prior examinations in their workspace. The physician white board from the visual communication trial has minimized interruptions of the radiologists. With the execution of the lay letter mailing trial, it is estimated that 5000 patients each year will receive their results 1 day earlier.

The technologists have also become more efficient. The lead technologist trial and the technologist white board from the visual communication trial have eliminated the need for the technologists to search for an open examination room. The redefining roles trial has enabled the technologist to prepare the examination room before greeting the patient. Also, the physician white board from the visual communication trial has decreased the need for the technologist to search the different reading rooms in the department for a particular radiologist. Unfortunately, the portable electronic device trial did not result in a practice change, since the technologists reported that the electronic tablet was too cumbersome and the smart phone screen was too small to read. In addition, the technologists were afraid of dropping the devices.

The evaluation of IT systems allowed us to uncover many sources of inefficiency in the mammography reporting system, and in their integration with the departmental PACS and electronic medical record. With the help of the IT department, investigations of both the workstation and the reporting system were launched to determine if improvements in the existing technology could be made or if alternatives were necessary. After intensive analysis, the section has decided to transition to a PACS-based mammography workstation. Also, a major investigation of the current reporting system is ongoing, and alternate reporting systems are being evaluated.

Many additional benefits were gained by implementing these trials. The aide assigned to direct patients to the changing room as part of the patient wait time trial reported increased job satisfaction, since she was now able to experience direct patient contact. The addition of a printer to the assistant’s office as part of the printer relocation trial has simplified her workflow. The technologists reported feeling less stressed because of a more predictable and equitable distribution of work. Clinicians from the adjacent breast care center made use of the physician white board to help them locate a specific radiologist in the section. Overall, a more cohesive work environment developed.

**Summary**

The application of lean principles to our screening mammography workflow has improved the efficiency of the section while decreasing wait times for our patients. The workflow changes were not just tested and forgotten; those that were found to favorably impact efficiency were immediately implemented sectionwide. Adoption

<table>
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<th>Table 6 Results of Electronic Work List and Digitizer Trials</th>
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<td>Average Radiologist Read Times</td>
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<td>Resident-fellow preliminary report (min)</td>
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*The three evaluations were conducted on 2/6/2012, 3/19/2012, and 4/18/2013, respectively.
†Number of report readings evaluated not available.
of the lean approach has provided the structure and the individualization and engagement of personnel for quality improvement that no previous outside consultant was able to deliver. It has evoked a culture change in the section, fostering equal involvement of all staff as agents of change, respect for all members’ opinions, and openness to new ideas. Section members have come to see (a) the importance of direct observation for fully understanding a process and for offering workable solutions to problems, and (b) the power of data-based decision making. Direct observation has also led to a better understanding of each member’s role and a greater respect for his or her contribution to the section.

This is not to say that the lean transformation undertaken by the section was easy. We soon realized that the enthusiasm of the core lean team as they tackled a problematic workflow was not always shared by the rest of the breast imaging technologists and physicians. In fact, some trials were met with outright resistance. We found that most of the resistance stemmed from a fundamental reluctance to change, a lack of understanding of the trials and how they would impact one’s daily work, and a perception that one was no longer a part of the larger breast imaging team but was instead part of a marginalized group of “nonlean” workers. To restore the sense of teamwork, a “mini boot camp” was offered to introduce those not involved in the lean sessions to the concepts of the lean approach. In addition, constantly communicating about the trials and their purpose, actively seeking feedback and implementing suggestions, and sharing trial-based data that led to concrete improvements in efficiency engaged all members of the section. We realized that success in process improvement could not be achieved overnight and does not have a finite endpoint, but is an ongoing endeavor that requires constant monitoring and upkeep.

Addressing screening mammography workflows is only the starting point for improving the efficiency of the section. Now that we have learned the principles of the lean approach and recognize the benefits that their adoption produces for our patients, productivity, and job satisfaction, we can use these successes as a springboard for future quality improvements. We now look forward to applying lean principles to our more complicated diagnostic mammography and ultrasonography workflows.

Acknowledgments.—The authors thank Aneesh Suneja, Jennifer Eldredge, and Terry L. Schwartz.

References
The lean approach strives to eliminate all forms of waste within a given process, so that fewer resources are required and less cost is generated in achieving equal or greater levels of productivity.

The lean approach is more than just a set of written principles for quality improvement; it is a process improvement philosophy that seeks continuous change in how the workers within an organization think and act, thereby transforming how the entire organization approaches work and management. With this unique philosophy, all members of a team are empowered by being directly involved in identifying problems, generating solutions, and implementing new plans, thus creating a culture change. This “lean transformation” is what sets the lean approach apart from other quality improvement methods.

Waste can fall into one of seven categories: motion, transportation, inventory, waiting, defects, overprocessing, or overproduction.

A fundamental lean principle is the direct observation of processes where they occur (going to the *gemba*) to identify waste.

The lean tool known as “5-S” focuses on enhancing visual order and organization in the workplace to optimize efficiency. The five components of 5-S all begin with the letter S: sort, straighten, shine, standardize, and sustain.
WHAT IS THE LEAN APPROACH?

**Question 1:** Which of the following are key words and phrases that describe what the lean approach strives for?

- A: Elimination of waste within a given process
- B: Fewer resources required
- C: Less cost generated to achieve equal or greater levels of productivity
- D: B and C
- E: All of the above

**Question 2:** Which of the following are end goals of the lean approach?

- A: Improved productivity
- B: Decreased cost
- C: Increased customer satisfaction
- D: Less staff needed
- E: A and C

**Question 3:** The lean approach has been used to evaluate which of the following?

- A: MR imaging examination times
- B: Mammography workflow
- C: Patient throughput
- D: All of the above

LEAN METHODOLOGY

**Question 4:** Is it TRUE that the first step in a lean transformation is to identify the customer and define “value” from his or her perspective?

- A: YES
- B: NO

**Question 5:** Is it TRUE that waste is defined as: “Anything that utilizes resources but does not add value to the process?”

- A: YES
- B: NO

RESULTS

**Question 6:** Which of the following are categories that waste can fall into?

- A: Sort, straighten and standardize
- B: Motion, transportation and inventory
- C: Both of the above
- D: None of the above

**Question 7:** The described project resulted in which of the following?

- A: A 30% smaller workforce
- B: Decreased patient wait times
- C: Improved efficiency for the technologists
- D: Faster report turnaround

**Question 8:** Before the patient wait time trial was implemented, the average wait time for a screening mammography patient was about 11 minutes. After the trial the average wait time was which of the following?

- A: 9 minutes
- B: 7 minutes
- C: 3 minutes

**Question 9:** Some trials were met with outright resistance because of which of the following?

- A: A fundamental reluctance to change
- B: A lack of understanding of the trials
- C: A perception that one was part of a marginalized group of “nonlean” workers
- D: All of the above

**Question 10:** Is it TRUE that direct observation for fully understanding a process is critically important in the lean approach?

- A: YES
- B: NO
ANSWER FORM

(If your personal details have not changed, only complete the sections marked with an asterisk)

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*Initials and Surname*

*Employer*

*Place of employment*  **Fax No**

ID Number  ***Cell No**

E-mail Address

*How would you like to receive your results for this activity (IAR)*  **FAX**  **EMAIL**  **POST**

*Time spent on activity*  ____Hour  _____Min  **Is this for an audit**  **YES**  **NO**  **When did you receive the activity**

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PRACTICE POLICY AND QUALITY INITIATIVES – USING LEAN PRINCIPLES TO IMPROVE SCREENING MAMMOGRAPHY WORKFLOW

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Signed:__________________________  Date:____________________

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