HETA 99-0093-2749
University of Medicine and Dentistry of New Jersey
St. Peter's University Hospital
Piscataway, New Jersey

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Dan Habes and Sherry Baron of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing was performed by Ellen Blythe and Elaine Moore. Review and preparation for printing was performed by Penny Arthur.

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NIOSH ergonomics evaluation of sonographers at St. Peter's University Hospital

The hospital asked us to help identify the sources of discomfort experienced by sonographers and if there was something they could do better to lessen the pain.

What NIOSH Did

Looked at the movements made by sonographers when they work.

Measured how much effort is needed to press down on a patient's abdomen.

Looked at what the sonographers use, such as the exam table, the chair, the imaging machine, and the scan head.

Asked the sonographers to show where it hurts.

What NIOSH Found

Most of the time sonographers reach too much and too far to do their job.

The reaching and other bad postures often happened because the chairs and tables were not adjustable.

The scan head was too small for most sonographers to handle easily.

Some of the discomfort experienced by the sonographers was because of too little rest during an exam.

What St. Peter's University Hospital Managers Can Do

Provide adjustable exam tables and chairs for the workers.

Provide pillows, cushions, and straps for the scan head so workers can rest their arms and hands.

Build special rooms for the different kinds of exams that are done.

Find a scan head that fits the hand better or make a handle for the one that's used now.

What St. Peter's University Hospital Employees Can Do

Make sure the bed and the chair fit you before starting an exam.

Ask the patient to lie at the edge of the bed to reduce reaching. Ask the patient to move during an exam to let you rest your arm on their leg so you won't get tired so fast.

Stand whenever you can to reduce reaching. A chair made for sitting and standing will make it easier for you to do this.

Talk to each other about what you do to relieve pain while you work. You may find out something you can do that you didn't know about.

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National Institute for Occupational Safety and Health
NIOSH

Health Hazard Evaluation Report 99-0093-2749
University of Medicine and Dentistry of New Jersey
St. Peter's University Hospital
Piscataway, New Jersey
August 1999

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SUMMARY

On February 1, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Safety Manager of the University of Medicine and Dentistry of New Jersey for a health hazard evaluation (HHE). The request stated that ultrasound technologists at one of the University's antenatal testing units were experiencing neck, shoulder, and arm pain from performing trans-abdominal and trans-vaginal sonograms on pregnant women.

On March 9-11, 1999, NIOSH representatives conducted a site visit at St. Peter's University Hospital, where the antenatal unit is located. The investigation included videotape analysis of several ultrasound procedures and distribution of a musculoskeletal disorders symptom questionnaire/body map to the ultrasound technologists.

Physical stresses associated with the performance of trans-abdominal and trans-vaginal sonograms included awkward postures of the shoulder and wrist, long reaches, sustained static forces, and pinch grips. Many of the factors associated with physical stress to the workers were related to the design and lack of adjustability of work station components and equipment.

The hospital employee health staff had previously conducted a thorough examination of the musculoskeletal health status of the sonographers prior to the NIOSH evaluation, which had documented shoulder and hand disorders. Body map discomfort diagrams were received from six ultrasonographers present during the NIOSH site visit; five out of six reported some neck or right shoulder and arm discomfort.

NIOSH investigators conclude that the upper extremity discomfort experienced by ultrasound technologists at St. Peter's University Hospital antenatal testing unit is associated with awkward postures, sustained static forces, and repetitive movements that are a part of their job. Many of the factors causing pain to the ultrasound technologists are related to and exacerbated by the design of the ultrasound transducer and the lack of adjustability of key components of the work station: the monitor, the keyboard, the chair, and the patient examination table. Recommendations for changes in equipment and addition of work place components intended to relieve the workers' discomfort are contained in this report.

Keywords: SIC 8062 (Hospitals), sonography, trans-abdominal and trans-vaginal ultrasounds, repetitive motion disorders, static forces, awkward postures

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INTRODUCTION

On February 1, 1999, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Safety Manager of the University of Medicine and Dentistry of New Jersey for a health hazard evaluation (HHE). The request stated that ultrasound technologists at one of the University's antenatal testing units were experiencing neck, shoulder, and arm pain from performing trans-abdominal and trans-vaginal sonograms on pregnant women.

On March 9-11, 1999, NIOSH representatives conducted a site visit at St. Peter's University Hospital, where the antenatal unit is located. The site visit included an opening conference attended by management and union representatives, videotaping of several ultrasound procedures, and distribution of a musculoskeletal disorders symptom questionnaire/body map to the ultrasound technologists. A closing conference was held on the afternoon of March 11, 1999.

BACKGROUND

St. Peter's is an affiliated hospital of the Robert Wood Johnson Medical School, which is part of the University of Medicine and Dentistry of New Jersey, along with five other educational institutions. The antenatal testing unit is primarily a referral center that specializes in high-resolution ultrasound procedures. The clinic may receive routine referrals from gynecologists or from other facilities that cannot perform the comprehensive procedures that are a specialty of St. Peter's. The high-resolution ultrasound examinations performed by the antenatal testing unit are extensive and often lengthy. The most common procedures performed are biophysical profiles, complete fetal evaluations (Level II exams), and Doppler studies.

Job Descriptions

Staffing at the antenatal testing unit consisted of 11 ultrasound technologists and 2 perinatal physicians. Work schedules were 5 days per week, with 7 scanning hours per day. During a typical workday, each sonographer performs about ten ultrasounds, most of which are trans-abdominal. Each sonographer is trained for trans-abdominal and trans-vaginal examinations. Ultrasound procedures take place in a room equipped with an examination table (bed) for the patient, a chair or stool for the sonographer, and an ultrasound imaging system. The six examination rooms at the clinic were not all configured the same. The ultrasound system is a free-standing machine on wheels equipped with a keyboard, other controls, and a monitor. The keyboard and monitor are not height-adjustable, but on some units the monitors can be adjusted for tilt. Throughout the six rooms, keyboard heights ranged from 36 to 38 inches, and mid-screen monitor heights ranged from 47 to 53 inches. Some rooms had adjustable chairs with arms and backrests while others had standard stools. The stools were height-adjustable by loosening a knurled knob, but it was difficult to turn. All but one examination room was equipped with a standard examination table that was 32 inches high and 27 inches wide. These beds were not adjustable and could not be moved. The examination table in the other room was a stretcher on wheels; its height could be adjusted from 30 to 37 inches using a foot pedal. The stretcher was 24 inches wide.

The ultrasound images are captured with a transducer or sensor called the "scan head." For trans-abdominal scans, the scan head used is oval-shaped, 3 inches wide, about 4 inches long, and 1 inch thick. The transducer used for trans-vaginal scans is long and thin with a small imaging sensor at the tip and an inline handle at the other end.

METHODS

Ergonomic

The ergonomics evaluation consisted of observation and videotaping of several of the two types of ultrasound procedures. The purpose of the video tape was to document and measure the visible aspects of the ultrasound procedures, such as postural demands, sustained application of muscular force, and repetitiveness for the sonographer. Videotape analysis also enables the input of body position data into computerized biomechanical models. This information was extracted from the video through playback analysis. Work station and work area measurements were also made with a tape measure, and the force to press down on a patient's abdomen with the scan head was simulated using a push/pull force meter.

Medical

A complete medical evaluation of the ultrasonographers, which included a comprehensive questionnaire and musculoskeletal examination, had previously been conducted by the employee health staff of the hospital, and had documented several shoulder and hand disorders. Therefore, the medical portion of this HHE was limited to a brief symptom survey with a body map discomfort diagram. The ultrasonographers who were present during the evaluation were asked to indicate on the map the areas of the body in which they experienced pain or discomfort.

EVALUATION CRITERIA

Overexertion injuries, such as low back pain, tendinitis, and carpal tunnel syndrome, are often associated with job tasks that include: (1) repetitive, stereotyped movement about the joints; (2) forceful manual exertions; (3) lifting; (4) awkward and/or static work postures; (5) direct pressure on nerves and soft tissues; (6) work in cold environments; or (7) whole–body or segmental vibration.[1,2,3] The risk of injury appears to increase as the intensity and duration of exposures to these factors increase and recovery time is reduced.[4] Although personal factors (e.g., age, gender, weight, fitness) may affect an individual's susceptibility to overexertion injuries/disorders, studies conducted in high–risk industries show that the risk associated with personal factors is small compared to that associated with occupational exposures.[5]

In all cases, the preferred method for preventing/controlling work–related musculoskeletal disorders (WMSDs) is to design jobs, work stations, tools, and other equipment to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. Under these conditions, exposures to task factors considered potentially hazardous will be reduced or eliminated.

The criteria used to evaluate the ultrasound procedures at the antenatal clinic of St. Peter's University Hospital were work place and job design criteria found in the ergonomics literature and the biomechanical outputs obtained from the Michigan 3-Dimensional Static Prediction Program.[6]

RESULTS

Ergonomic

Trans-Abdominal

Nine trans-abdominal ultrasounds were videotaped, averaging 18.5 minutes (range = 3.5 to 33.8). Among the nine were two follow-up evaluations performed by the perinatologists on duty at the time of the evaluation. The examinations performed by the doctors take place after the technologists have completed a procedure such as a Level II exam or a biophysical profile, and are intended to review/verify the findings of the full procedure and provide the doctor with an opportunity to interpret and/or explain results to the patient. As such, the follow-ups take less time than the full procedures, reducing the average time per procedure observed during this evaluation. The main ergonomic stress factors observed were awkward postures, mainly right shoulder flexion and abduction, sustained static forces, and various

types of pinch grips while maneuvering the transducer. Figure 1 shows some common wrist and finger grasp postures. The presence of awkward wrist postures varied because the manner in which the sonographers moved the sensor depended on the size of the patient. In general, if a patient was early in her term and the abdomen was fairly small, the ultrasound technologist would maneuver the sensor predominantly with shoulder movements. For patients further along in the pregnancy, having a larger abdomen, sonographers would use more wrist flexion and extension to reach the near and far areas of the abdomen.

The position of the equipment with respect to the sonographer and patient resulted in twisting of the neck to the left to view the monitor, and flexion and abduction of the left shoulder and extension of the elbow while operating the touch screen, the track ball, and the keyboard.

The shape of the abdominal transducer resulted in several distinct types of grips used by the sonographers. Although the transducer was curved and rounded at the edges, its shape from a top view (which determines the grip type) was rectangular (1x3 inches). Consequently, if the sonographer held the sensor along the narrow side, the grip would be a thumb opposing fingertips pinch grip; if the sensor was held along the wide side, the grip would be a power grip. The most common type of grip observed was one in which the sensor was held in the palm of the hand with the thumb on one side (3x4 inch dimension) and three or four fingers on the other side. Figure 2 shows the three most commonly seen methods of grasping the scan head.

The video analysis indicated that the configuration of the examination room influenced the type and degree of some of the postures assumed by the sonographers, particularly shoulder flexion and abduction angles. One of the sonographers was observed performing procedures in rooms having the two types of patient beds. In the room equipped with the 27-inch wide standard bed, shoulder abduction angles approached 70-80° for reaches to the far side of the patient. In the room with the adjustable stretcher that was 24 inches wide, shoulder abduction angles never exceeded 50° and were typically 45° or less (See Figure 3). When the narrow bed was used, the patient was usually positioned at the edge of the bed, providing leg support for the sonographer's arm if it was needed. With the patient lying in the middle of the 27-inch bed, there was clearance between the edge of the bed and the patient, making it more difficult for the sonographer to rest his/her arm on the patient's leg.

Several of the sonographers were asked to grasp a push/pull force meter as if it were a transducer and demonstrate the average and peak downward forces exerted while obtaining images from a patient. Samples taken from five of the sonographers applying "typical pressure" averaged 4.0 pounds (range = 2.6 to 4.8) and peak forces averaged 8.5 pounds (range = 3.5 to 14.6).

Video analysis also indicated that the transducer was held in the hand during the entire procedure, even when downward forces were not being applied to the patient's abdomen. Sustained static forces lasting 30 seconds were common and some lasting a minute or more were observed. These types of static exertions were often done with the elbow unsupported.

Input of force measurements and shoulder angles into the Michigan 3-Dimensional model indicated that 90% of the female population has the strength to press down 10-15 pounds with a shoulder abduction angle of about 40°, but that only 70% have the shoulder strength to exert this amount at 80° abduction. In addition, the moment at the shoulder while exerting these forces is 64% greater at 80° abduction than at 40° abduction.

Trans-Vaginal

Two trans-vaginal ultrasounds were observed and videotaped, lasting 1.5 and 1.2 minutes (average = 1.4 minutes). The main ergonomic risk factors associated with the trans-vaginal procedures are extension and abduction of the shoulder, extension of the wrist, and sustained static grip

forces. These postures are a result of the patient's leg being between the sonographer's right arm and the equipment. The transducer is grasped in a power grip but because the patient's leg forces the sonographer to elevate the upper arm, the grasp must be made with the wrist in full or nearly full extension.

Medical

Not all of the sonographers were at the clinic during the time of the evaluation, and therefore only six surveys were completed. Five of the six respondents reported pain or discomfort, which was located in the neck region and in the right shoulder, elbow, and hand/wrist regions. None reported any left-sided shoulder or arm discomfort.

The NIOSH medical assessment was limited because prior to the site visit, a complete medical evaluation, including a detailed symptom questionnaire, was conducted on each sonographer under the direction of the clinic medical director. The results of this medical evaluation are not available at this time.

DISCUSSION

Trans-Abdominal

The musculoskeletal problems experienced by sonographers performing various types of ultrasound examinations have been documented in the medical literature.[7,8] Much of the ergonomic information contained in these articles is qualitative, and not related to specific job factors, but it is likely that the setup of equipment and ultrasound procedures used by the described workers is similar to that observed at St. Peter's University Hospital.

Equipment and Examination Room Components

The key to understanding the problem of the ultrasound technologists at St. Peter's is recognizing that these jobs are comprised of a variety of musculoskeletal injury risk factors which primarily result from, and are exacerbated by, poor design of workplace components. If the height of the examination table and the chair used by the sonographer could be easily adjusted, the extent of reaching could be minimized. Furthermore, if the sonographer's elbow could be supported when long reaches are unavoidable, the stress to the shoulder and neck muscles could be reduced. Many of the video sequences analyzed indicated that during long reaches, the sonographer's elbow was just above the patient's leg. A saddle-type pad placed on the patient just below the abdomen, but resting on the examination table, could provide support for the technologist's elbow during long reaches.

A recent study evaluating the effects of arm supports on shoulder and arm muscle activity found that the normalized electromyographic (EMG) activity of the deltoid and trapezius muscles of subjects performing simulated assembly tasks was 1.8 to 4.5 times greater when the elbow was unsupported versus supported.[9] These EMG differences were found on subjects performing a task where reach distances across a horizontal table were about 6 inches. Elbow support would likely benefit the sonographers at St. Peter's even more since they were observed to reach as far as 24 inches while recording ultrasound images from patients.

Alternative methods for supporting the elbows of sonographers while they work are in development. Researchers at Simon Fraser University (British Columbia, Canada) are studying the feasibility of using suspended slings to support the elbows of technologists performing ultrasound procedures.[10] The results of these studies are not yet available, and the practicality of using slings during ultrasound procedures has not been reported. However, if research findings indicate that slings are effective in reducing muscular fatigue, they may eventually be used to relieve the discomfort of sonographers, particularly by those who perform many procedures per day.

A pad for elbow support would not be as useful when sonograms are performed on a late term patient during which a sonographer's elbow may be several inches to a foot above the patient, but would be effective in many other procedures performed at St. Peter's. With late term patients, reach distances would be reduced if the sonographer could stand while scanning the patient, but standing causes a misalignment between the sonographer and the fixed locations of the keyboard and monitor. The ultrasound equipment used at the clinic was clearly designed for a seated sonographer. A 50-50 mix of males and females has an eye height while standing ranging from 56.8 inches (5^{th} percentile) to 67.8 inches (95^{th} percentile).[12] However, the highest monitor height observed at St. Peter's was only 53 inches. Moreover, it might be cumbersome for the technologist to repeatedly get in and out of a chair, particularly if it were adjusted such that the sonographer's feet were not on the floor. In cases where alternating between sitting and standing during a procedure might be comfortable for the sonographer, a sit/stand stool would be a possible solution. Standing periodically (to reach less) would also minimize the awkward wrist postures that were observed during long reaches with a large patient.

Scan Head Design

Another work place design feature which adds to the musculoskeletal discomfort of the workers is the design of the scan head. Regardless of how it is held, the grip is either a pinch along the narrow edge or a power grip across a span that is too large. The shape of the scan head may have been the reason the sonographers alternated among the several grip types observed; apparently none was comfortable for very long. The most desirable shape of a handle is round or elliptical, 1.5 inches in diameter.[11] When the sensor is grasped along the thin dimension, either in the middle or at the edge, a 1 inch pinch grip is used. A pinch grip is undesirable because force capability is only 15 to 25 percent that of a power grip[12] and would accelerate the fatigue of a sonographer's muscles. When the power grip is applied along the 3 inch edge, the thin edge of the transducer digs into the thenar aspects of the thumb and the soft tissue of the proximal digits. The deleterious effects of either of these grips are further intensified by the sustained static forces (downward and to hold the scan head) that are required to obtain some of the ultrasound views. If some conducting gel works its way onto the transducer, the grip forces needed to hold and maneuver it are even greater. Figure 4a shows a closeup of the scan head and a design which is no longer in common use. The older design gave way to the smaller, more compact newer design because a smaller imaging surface was needed for modern ultrasound procedures. Nonetheless, the older design has more of the desirable design characteristics outlined above than the newer scan head design. The older scan head is wider and longer (to accommodate the length of the hand), and the cord location at the side does not interfere with the hand grip. The older design would be even better if it were more egg-shaped, but it nonetheless allows a grip which is much more like a power grip than what the newer design allows. The best features of each design could be incorporated into one tool by adapting a smaller imaging surface to the older tool or by developing a transducer that has a handle portion "detached" from the "functioning" portion, as is the case with most tools.

Sustained Muscular Exertions

For light exertions, such as the 4 to 15 pounds that was demonstrated by the sonographers, ergonomics guidelines suggest that a rest period equal to the length of the sustained muscle exertion should take place before the exertion is repeated.[12] That is, if a sonographer pushes down on the abdomen for a period of 15 seconds to obtain a necessary fetal view, he/she should release the scan head and recover for 15 seconds before proceeding with the examination. For exertion times lasting 1 minute, recovery times of 100 seconds are required. Video analysis indicated that recovery times were never more than just a few seconds, and the sonographer rarely, if ever, let loose of the transducer.

Biomechanical Issues

A moment is a bending force produced at a point of reference (fulcrum) when a force is applied to a perpendicular lever. In the case of the sonographers, the reference point is the shoulder, the force is the weight of the arm and the downward force applied to the scan head, and the lever is the length of the outstretched arm. A model that most individuals understand is that of two children on a seesaw. If one child is further away from the fulcrum than the other, more force (or a heavier child) must be placed on the other side of the fulcrum to keep the seesaw level. For the sonographer to keep an unsupported arm elevated during an examination, the downward force must be counteracted at the shoulder in the form of shoulder muscle contraction. The longer the lever arm, the greater the moment and required muscle forces at the shoulder. If the elbow is supported, or if the hand is held closer to the shoulder, the counteracting shoulder muscle contractions needed are reduced.

The 3-Dimensional biomechanical model used to estimate strength percentiles and moments about the shoulder while using the transducer indicated that musculoskeletal stress could be reduced with more neutral postures of the shoulder and forearm, even though the forces and moments observed were not excessive in magnitude. A characteristic of the 3-D biomechanical model is that it does not take into account repetition. It calculates forces and moments based on what it assumes to be a single posture. Therefore, if the 3-D model indicates a benefit to using more neutral postures during exertions assumed to occur only once, consider the reduction in accumulated muscle fatigue that could be achieved during the repetitive and sustained exertions that occur during an ultrasound examination.

Scanning Technique

The manner in which the sonographer approaches the task of performing an ultrasound exam could have an effect on musculoskeletal discomfort level during a procedure. Many of the technologists performed the procedures with total regard for the patient and little for themselves. They rarely asked the patient to move up or down or to lower her leg to improve their own postures or to rest their arm on the patient's leg or the edge of the bed. However, the perinatologists were more inclined to adjust the equipment or the patient's position to relieve their postural stress. At one point, one of the doctors moved his chair and ultrasound equipment toward the foot of the bed to reduce shoulder extension and to allow him to rest his forearm on the patient's leg while trying to get a view of the fetus at the base of the patient's abdomen. Improved equipment such as a bed that can be easily moved and adjusted for height and fore-aft position of the patient, would encourage all of the sonographers to make minor adjustments to relieve their pain.

Other Issues

Another incidental stressor to the sonographers while performing ultrasounds is the moment at the wrist from the weight of the cord, which is positioned at the top of the transducer. No measurements were made, but the weight of the thick cord must be opposed by muscle contractions for the entire length of the procedure. One of the sonographers was observed to support the weight of the cord by wrapping it around her shoulder. This technique seemed to have merit, and all sonographers who have not tried this approach should consider evaluating this minor modification in their technique.

None of the sonographers complained of any left arm pain while using the keyboard or other imaging controls, but most reported discomfort in the neck due to twisting the head to view the monitor positioned to their left. The head postures of the sonographers could be made more neutral with the monitor placed in the normal line of sight, which would be across the bed at about the patient's left shoulder.

Trans-Vaginal

We observed only two trans-vaginal sonograms, each of which was part of a more detailed trans-abdominal procedure. The typical trans-vaginal procedure is one involving fertility studies, where sustained periods of static postures take place

while the technologist counts follicles in the uterus. The postures observed during these procedures could not easily be sustained for long periods of time. Sonographers told the NIOSH investigators that during lengthy trans-vaginal procedures, they often stop the procedure and move the equipment toward the foot of the examination table to improve shoulder and wrist postures. Such a remedial measure is not surprising and suggests that a dedicated setup for trans-vaginal sonograms should be sought. Ideally, the sonographer and the ultrasound equipment should be in front of the patient, which would eliminate the need to reach over the patient's leg to control the transducer with the right hand while operating the keyboard and other controls with the left hand.

CONCLUSIONS

1. The ultrasound procedures performed at St. Peter's University Hospital involve several ergonomic risk factors that contribute to the musculoskeletal pain experienced by the workers.

2. The implementation of improved equipment and components such as adjustable chairs and patient beds would reduce the discomfort experienced by the sonographers.

3. The reaching and muscular force exertions required of the sonographers result in stressful moments and forces on the muscles and joints, and the major ergonomic stress factor is sustained static muscle exertions without adequate recovery between exertions.

4. Use of cushions, pads, and procedural changes aimed at minimizing reaching with unsupported elbows would reduce the biomechanical load on the workers. This would in turn reduce fatigue and the onset of muscular pain and discomfort.

5. A design for the trans-abdominal transducer that conforms to generally-accepted ergonomic principles for tool handle design would reduce pain at the hand and wrist of ultrasound technologists.

RECOMMENDATIONS

1. Furnish all examination rooms with an adjustable chair and adjustable bed so that the sonographers can optimize their position with respect to the patient and the ultrasound equipment. The bed should be as narrow as possible to allow the patient to be as close to the sonographer as possible. The one sonographer who was evaluated using the 24-inch-wide bed and the 27-inch-wide examination table was able to reach to the far side of the patient with less shoulder abduction when using the narrower bed. The bed should be height-adjustable between about 28 and 40 inches with an electric foot pedal, and should have fore and aft patient position adjustability.

2. Provide elbow support for the sonographers to reduce physical effort and biomechanical loads when reaching to obtain ultrasound images. The support can be as simple as a wedge or a pillow placed between the patient and the sonographer, or more elaborate like a saddle-type cushion placed over the patient resting on the edges of the bed.

3. Evaluate the use of sit/stand stools to enable sonographers to stand when making reaches to the far side of the patient. The success of providing the option to stand would depend on the ease of modifying the keyboard and monitor height to accommodate standing. One approach would be to customize an examination room for each sonographer or sonographers of similar size such that height of the monitor and keyboard would be comfortable for sitting and standing. For taller workers, the ultrasound equipment may have to be placed on an elevated platform to accommodate standing, but the chair and bed could be adjusted to fit the chosen height.

4. Customize an examination room for trans-vaginal examinations. As noted in the Results and Discussion sections, the placement of the ultrasound equipment at the head of the examination bed forces the sonographer into severely awkward shoulder and wrist positions.

The solution is to place the equipment in front of the patient so that the sonographer can operate the keyboard and monitor while manipulating the transducer with neutral shoulder and wrist postures.

5. Evaluate the possibility of adding an auxiliary monitor positioned in the line of sight of the sonographer to eliminate awkward neck postures. An additional remote monitor would allow the keyboard height to be adjusted independently of the monitor, which would simplify the raising of the entire imaging unit as recommended in item #3 above. A method of detaching the monitor from the ultrasound equipment for purposes of height adjustment without relocation would also improve the work station and benefit the sonographers.

6. Add an auxiliary handle to, or modify the existing handle of, the trans-abdominal scan head to allow for a power grip while handling and maneuvering the unit. The handle should be elliptical or round in shape and able to be fashioned without affecting the imaging hardware located inside the scan head. The handle should be 1.5 inches in diameter and at least 4 inches long. A flared edge at the bottom of the handle to support the thenar portion of the handle would be desirable. The texture of the handle should be as slip resistant as possible while adhering to medical standards for cleaning and disinfecting. The cord on the redesigned scan head should be as thin as possible for minimum weight and torque. A modified tool handle meeting the above design criteria that is available with some portable ultrasound units can be seen in Figure 4b. As noted in the Discussion section, the older design shown in Figure 4a is shaped more for a power grip than the newer design, but may need a smaller imaging surface and/or detached handle to accommodate the needs of modern procedures. Whatever the design, the handle should also be equipped with a strap that would enable the sonographer to relax the hand during the procedure without letting loose of the transducer. Attaching a tool to the hand so that workers can relax their grip between periods of exertion has been shown to be a successful intervention in the meatpacking industry.[13]

7. Develop alternative procedures for conducting ultrasound examinations that emphasize the comfort of the sonographer without comprising the quality of the services performed. This approach would involve sonographers observing and working with each other to establish methods for minimizing stress such as wrapping the cord around the shoulder to reduce forces while handling the transducers, asking patients to reposition themselves during a procedure, taking short rest breaks during a procedure to relieve muscle fatigue, and adjusting the position of pillows and cushions that may be used. Many of these administrative measures would be more feasible and acceptable as adjustable equipment and remedial aids are implemented. Taking rest breaks during a procedure may add to the total time of an examination, but short breaks need not take too much time because there is opportunity to rest while the sensor is moved about the patient or when the patient is moved for a better view, provided the sonographer can let loose of the scan head during these transitional periods.

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