Workstations to Reduce the Incidence of Work Related Injury in Diagnostic Medical Ultrasound

Final Report to the Occupational Health and Safety Agency for Healthcare in British Columbia

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We identified a number of risk factors for work-related musculoskeletal injury (MSI) in previous worksite and laboratory assessments of the ergonomics of diagnostic medical ultrasound. These comprised principally awkward and static postures with high forces being a contributing factor only in certain cases. We determined that the location of the monitor, control panel, and the design of the ultrasound table are the key elements that constrain the sonographer’s posture. In particular, the sonographer frequently adopts postures in which the neck and trunk are rotated, the trunk is at an angle with respect to vertical and the shoulder is abducted. Although not necessarily exerting large forces, the sonographer may maintain these postures for prolonged periods of time while obtaining ultrasound images. Based on these assessments we proposed to redesign ultrasound workstations and conduct an intervention study to test their efficacy in reducing the risk of MSI.

We undertook the construction of four ultrasound workstations, two for use in routine abdominal ultrasound procedures performed during pregnancy, one for use in special procedures performed during pregnancy and one for use in endovaginal ultrasound procedures. Each workstation was designed for installation in a specific room at the ultrasound department of B.C. Women’s Hospital. Our original intent was to design the workstations to fit with the hospital stretcher or ultrasound table found in each room. However, after conducting an inventory we found that most of the stretchers and ultrasound tables in the department were incompatible with the new workstation design. Consequently, we decided to approach Biodex Medical, a manufacturer of ultrasound tables, to undertake modifications to our specifications. We chose Biodex Medical because the design and construction of their ultrasound tables was most amenable to the modifications that we had in mind. We had not budgeted for this equipment in our research
proposal so although the manufacturer agreed to sell 3 units to us at a
discounted price, it was necessary to look for an additional source of
funding.

Our proposed modifications to the ultrasound workstations included the
introduction of an adjustable support frame for a detached monitor, an
overhead suspension system for the transducer cable and a special chair
with a swing arm to support a detached console. In reviewing design
options, we decided that the swing arm to support the detached console
would be better mounted on the bed than the chair. Initially, we had
thought that it would be possible to design an interface that would allow
us to use a commercially available console. However, once we learned
more from the manufacturers about the hardware and software used in
operation of the console we realized that it would be necessary to design
and build customized switching and routing circuits for a detached
console. This also contributed additional costs that had not been
foreseen in the original budget. To deal with the additional costs we
submitted a proposal to OHSAH.

The mechanical design and construction were carried out at the BCIT
Technology Centre. The ultrasound tables were modified with posts and
adjustable arms to support a flatscreen monitor and a detached console.
It was decided that it would be less expensive to purchase commercially
available products for office ergonomics than to design and build support
arms ourselves. The support arms were purchased from a distributor of
Ergotron products. A customized support system for the ultrasound
transducer was designed and built by the BCIT Technology Centre.

The electronics design and construction were carried out in the
Biomechanics Lab at SFU. We received invaluable assistance from ATL
and GE Medical Systems, the manufacturers of the ultrasound units to
which our workstations were being adapted. Both manufacturers provided circuit diagrams and components. Some of the personnel at ATL were particularly helpful in responding to repeated requests for information and parts. In the case of GE, we were supplied with a complete console that was small enough to serve as a detached console. It was necessary only to add a solid support base and design and fabricate one printed circuit card with switches. ATL also supplied us with consoles. However, the consoles were too large to be used as detached consoles. Consequently, it was necessary to design a new console layout using a subset of the functions found on the original console. This was done for both the ATL HDI 5000 and ATL HDI 3000 models. In addition, an interface card and a switching card had to be designed and produced for each model. The interface cards proved to be a challenge because of the high density of signal lines and close spacing of the connector contacts. Several weeks were spent in debugging problems due to short circuits on the printed circuit card.

Shipment of the GE console took about 6 months. However, it required only a few weeks after that to test and debug the interface circuitry. The complete GE workstation was installed at B.C. Women’s Hospital in May, 2001. Unfortunately, it proved unusable because the ultrasound table, which comprised the central structure of the workstation, did not have the necessary adjustment features to accommodate all of the different patient positions necessary for certain special diagnostic procedures. Due to expense and design constraints it was not possible to find a suitable alternative, i.e., other ultrasound tables which had the necessary adjustment features could not be easily modified. Shortly thereafter, the GE equipment in the ultrasound department of B.C. Women’s Hospital was replaced with equipment from another manufacturer. As a result, the GE detached console no longer had any utility.
Rather than placing the GE ultrasound workstation in storage, we moved it to the laboratory of Dr. Tim Salcudean and Dr. Robert Rohling in the Department of Electrical and Computer Engineering at UBC. They have ultrasound equipment from several manufacturers and are conducting research into new applications of ultrasound and are developing image guided, robot assisted ultrasound technology. There is also an opportunity to conduct experiments related to the ergonomics of diagnostic medical ultrasound with specialized measurement systems available in their laboratory. The GE detached console is currently in storage at SFU since it is incompatible with any of the ultrasound equipment at UBC.

There were a number of delays in the development of the detached console for the ATL ultrasound units. In addition to the production of the interface cards, noted above, there were problems with the design of the enclosure. Because of budget constraints the BCIT Technology Centre fabricated the enclosure by literally cutting and pasting together pieces of the consoles donated by ATL. This created several problems. First, there was a problem in aligning the toggle switches with the conductive elements on the printed circuit board. Second, there was a problem with switches making reliable contact with the conductive elements because the distance between the keys and the printed circuit board was not uniform. Third, there was a problem with switches sticking. Debugging the circuitry and the problems with the enclosure was a time-consuming process. With each adjustment or iterative modification it was necessary to go to B.C. Women’s Hospital, partially disassemble their ATL ultrasound unit in order to install our modified circuitry, run tests and then reassemble their ultrasound unit so that it was in proper working order for the following day. On one occasion, the electronic hardware on the ultrasound unit was inadvertently damaged, although we were
unable to ascertain how this happened. We had run similar tests successfully on prior occasions and could not recall anything that we had done differently. Fortunately, the hospital covered the cost of repair and we were permitted continue testing our prototype console.

Our budget was sufficient only to purchase one flat screen monitor. This monitor was compatible with the video output of the GE ultrasound unit, but not the ATL ultrasound units. In order to proceed with the project we requested the loan of flat screen monitors from Sharp in August, 2001. The company graciously loaned us three monitors for a period of one year.

However, it was not until September 2002, that the first workstation for an ATL HDI 5000 ultrasound unit was properly functioning (see photo below). We decided to have sonographers test it on a trial basis before proceeding further with the study. The research assistant who had worked on the electronic interface was present during the first day of testing. The electronic interface functioned according to specifications throughout that day of testing. No problems were encountered with the detached console. To our knowledge only one sonographer subsequently ever tested all of the features of the workstation. She used it on one occasion and reported that the detached console functioned reliably for an entire day. However, shortly thereafter we received reports that sonographers who were using the main ATL ultrasound unit while the workstation was connected in parallel, but not being used, were encountering random errors when attempting to use certain function keys. Because of this we were asked to immediately disconnect the workstation. We did not have an opportunity to determine the cause of the problem. We suspect that it may either have been because the switches on the interface between the main unit and the detached console were not properly positioned or that the interface cables
introduced a delay because of their length. We had encountered such a problem with the GE console and were able to solve it by simply shortening the interface cables.

Without being able to run extensive tests, which would be disruptive to the normal routine of the ultrasound department we cannot diagnose the cause of the problem. Because the remote console did function reliably in preliminary tests we think that it should be possible to solve the problem relatively quickly if extensive tests could be run.

We received reports through Carrie Edwards, our worker liaison in the ultrasound department at B.C. Women’s Hospital, that a number of concerns had been identified with the design of the workstations. A list
was also independently compiled by Rick Hall, working for OHSAH. These concerns are listed in the table below.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Concerns</th>
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<tbody>
<tr>
<td>Ultrasound table</td>
<td>• adjustment steps for height and head angle too large</td>
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<tr>
<td></td>
<td>• no decline position</td>
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<tr>
<td>Chair</td>
<td>• ring at chair base prevents chair from being positioned close to workstation</td>
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<tr>
<td>Flat panel monitor</td>
<td>• poor resolution</td>
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<td></td>
<td>• image fades when viewed from an angle</td>
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<td>Monitor support arm</td>
<td>• too little range of motion</td>
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<tr>
<td></td>
<td>• difficult to position</td>
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<tr>
<td></td>
<td>• monitor post was distracting</td>
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<tr>
<td>Detached console</td>
<td>• control functions switch intermittently between panel and ultrasound machine</td>
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<tr>
<td></td>
<td>• too much friction in keys and toggle switches</td>
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<tr>
<td>Console support arm</td>
<td>• moves during use (no position lock)</td>
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<tr>
<td>Overhead support for transducer</td>
<td>• too much upward tension on cable</td>
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<tr>
<td></td>
<td>• awkward to use – in the way</td>
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These criticisms were not universal. For example, one sonographer, who used the workstation following time off for injury, felt that the overhead support for the transducer had a positive impact on her ability to continue working.

Most of the identified concerns could be addressed through redesign of the workstation, although some modifications could be costly.

- The concerns about the ultrasound table could be addressed by replacing the table with one from another manufacturer. However, if this were done it would probably not be possible to make the support arms for the monitor and console and the transducer support an
integral part of the ultrasound table. They would have to be stand alone units which would take up more space. In particular, there would not be sufficient space between the main ultrasound unit and the table for a stand alone support for the detached console. The alternative would be to add the required features to the ultrasound table manufactured by Biodex Medical, which would be costly.

- The concern with the chair could be addressed by switching to a chair that does not have a ring at the base, although then there would be no support for the legs. We have previously recommended that sonographers should stand while performing ultrasound scans, which would be a simple solution to this problem.

- The concerns with the quality of the image on the flat screen monitor can be easily addressed with new technology. There are very high resolution flat screen monitors now that can be viewed from acute angles. However, they are considerably more expensive than current CRTs.

- The concern about range of motion of the monitor support arm and the concern with its positioning could probably be addressed with a support arm that employs a different mechanism, such as a gas-assist mechanism rather than the current friction-spring mechanism. It should be possible to achieve better performance, although at additional cost.

- The concern of the support post for the monitor support arm being a distraction might be addressed by placing the post in a different position or supporting the monitor from an arm attached to the ceiling of the room.
• The concern of the support arm for the detached console moving during use could be addressed by replacing the current support arm with one that can be locked in position.

• The concern about the tension in the overhead support for the transducer is addressed by simply changing the cable tension. The transducer is supported by a balancer with an adjustable tensioning mechanism. The tension can be easily reduced. The injured sonographer who used the transducer support was able to adjust the tension adequately for her needs, although she uses both arms when performing ultrasound scans.

• The concern about the transducer support being awkward to use is probably an issue of familiarity. We believe that this issue can be addressed simply by becoming accustomed to using this feature of the workstation. The system was designed to be used with a different grip on the transducer, which is something that must be learned by practice. The rationale for this design was that it would promote hand positions that were less likely to pose risk of MSI.

While the project was underway two new ultrasound units were introduced to the market which have some potential to reduce the risk of MSI if used properly. However, the image quality of these systems is not yet on par with that of the major manufacturers. The first system is called Sonosite (www.sonosite.com). It is a portable unit with a single transducer attached. While the unit can be placed on almost any solid support near the sonographer, the monitor is integral to the console and cannot be independently positioned. The ability to connect an auxiliary monitor to the output would address this limitation. However, the
concerns about image quality would probably preclude its use for most diagnostic procedures in hospitals and clinics.

The second system is called Ultrasonix (www.ultrasonix.com) and was developed locally. It is more compact than ultrasound units made by other manufacturers and has an adjustable height monitor and swivel mounted console. The Ultrasonix unit can be positioned closer to the sonographer than other units, but it still has limited adjustment for the position of the monitor and console. The monitor cannot be placed in a position which would avoid twisting of the neck or trunk. We were disappointed that Ultrasonix did not consult with us in the design of the workstation layout even though we offered our assistance.

The feasibility of conducting an intervention study, as we had originally proposed, depends critically on the willingness of sonographers to participate. The current staff shortages at many hospitals make this very difficult. To complete our study would require considerable additional funding. At least $50,000 would probably be needed to make the recommended changes to the workstations. Also, the logistics of testing modifications would be simplified if we relocated the project to a hospital closer to SFU, such as the Royal Columbian Hospital. We have heard indirectly that sonographers at Royal Columbian Hospital would be interested in participating in the study, provided that the workstations can be appropriately modified.