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Ultrasound Ergonomics – A Practical Guide to Reducing the Risk of Musculoskeletal Disorders

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Preface

This paper was prepared with the help and support of a number of people, particularly staff in the Simpson's Centre for Reproductive Health at the Royal Infirmary of Edinburgh whose contributions are gratefully acknowledged. Whilst I have provided the ergonomics knowledge; advice and guidance on the clinical work of a sonographer was provided by Lynn Mackenzie, Superintendent Radiographer, RIE and Tracey Bellas, Clinical Application Specialist, Toshiba Medical Systems. I owe a huge debt to their insight and practical expertise relating to carrying out ultrasound scans.

1. Introduction

Musculoskeletal disorders (MSDs) are a significant problem in most occupational groups. According to the European Agency for Safety and Health at Work, 62 % of workers in the 27 Member States of the EU are exposed for at least a quarter of their working day to repetitive hand and arm movements and 46 % have work requiring them to maintain painful or tiring postures. As an occupational group, those carrying out ultrasound scans on a regular basis are no exception to this problem.

This paper takes an objective look at the ergonomics of ultrasound procedures. It looks at where the procedures are carried out; what equipment is used; and how they are performed; providing advice and guidance to help those undertaking these procedures on a regular basis reduce the risk of musculoskeletal pain and discomfort associated with their work.

The paper starts by looking at the transducer itself. How you hold and move the transducer when you are scanning can have a significant effect on your risk of suffering hand and wrist pain. Shoulder symptoms are another major problem amongst those who carry out ultrasound procedures and your arm posture when scanning provides the next focus as this will have a big impact on such problems. The focus then moves to your neck and back. Once again, pain and discomfort in these areas can be a real problem for those carrying out ultrasound procedures and how you sit (and whether you sit) are important issues. Finally, the paper looks at the bigger picture, briefly considering how you plan and organise your work.

Every effort has been made to make sure that the following guidance is practicable. However, it is recognised that you might not always be able to follow the guidance given all of the time, especially for some procedures. It is important to realise however that most MSDs are cumulative, with repeated and sustained exposure increasing fatigue, inflammation, etc. Even a short break, doing a different procedure or carrying out the same procedure slightly differently, will allow tissues to start the recovery process and help reduce the risk of problems.

It is also important to remember that the human body is designed for movement (many muscular symptoms arise from a prolonged lack of movement). There is no reason why joints can't be moved through their entire range from time to time

(and several reasons why they should be). Although the advice given in this paper refers to avoiding this posture or minimising that joint angle it is not a question of doing so at all costs. As with so many things it is a question of 'anything in moderation'. Thus, occasionally raising your arm above a certain angle to reach across a patient will not cause you any harm; whilst carrying out almost the whole procedure with your arm raised too high, time after time, is a different matter.

2. Creating an ergonomic work environment

2.1 The transducer

Historically, a number of studies have identified transducer cable weight and rigidity as contributing to musculoskeletal problems amongst those carrying out ultrasound procedures. The use of lighter, more flexible cables in modern transducers helps to reduce these factors.

Ideally, tool size should be adapted to the size of your hand, with larger tools for those with larger hands and vice versa. This is because the further your hand moves away from its 'neutral' (relaxed) shape the greater the potential tension and strain in the finger tendons. Large tools make you stretch the hand (and tendons).

Unfortunately, although this works as an abstract concept, transducer size is largely dictated by the technical requirements of the specific scan they are designed for and choosing different sizes for a given procedure is rarely an option. However, you should be aware of this in carrying out scans and, where possible, adapt your scanning style accordingly, for example by making a particular effort to avoid or reduce wrist flexion movements if you have small hands and are using a large sensor. This is particularly important when making transverse scans, when you are gripping across the transducer rather than it lying in your hand (Fig. 1).

The tighter you grip, the greater the tension in the tendons of the hand and wrist. Relax your hand when you can, especially if you are using a specialist transducer such as an intracavity probe. Some transducers, such as those in the Toshiba range are made of a non-slip plastic material to help maintain a good grip. These transducers also incorporate a 'shoulder' in their design. If using one of these try, where possible, to hold the transducer so that it 'fits' into the palm of your hand, with the shoulder against your hand or fingers so it can't slip so easily when you need to apply pressure, especially with those more amply proportioned patients or when performing DVT procedures. These design features will help you to use as little grip force as possible to maintain control. If you can't do this, or the probe is still slipping in your hand, wipe it or wear a thin glove to improve grip, rather than gripping it more tightly. A 'pencil' grip is best avoided as it is harder to prevent the probe from sliding through your fingers without gripping it tightly.

2.2 Scanning movements

Where possible, try to scan by moving your forearm, not your wrist. 'Bending' the tendons linking the fingers to the flexor/extensor muscles in the forearm when they are under tension gripping a transducer will increase any strain (Fig. 2). Extreme wrist flexion or extension postures will also increase the pressure in the carpal tunnel. If possible, try to adjust how you hold the transducer to avoid or reduce this.

Some procedures such as DVT procedures, or when scanning patients with a high BMI, need you to press harder than usual to get the correct image. This might also cause you to increase the grip force used to help prevent the transducer from slipping. Both factors will increase the tension in the tendons passing through the wrist. As mentioned earlier, where the transducer has a shoulder, using it to help prevent the transducer from slipping through your hand will help here. Wrist flexion/extension movements with these high levels of tension should be avoided altogether or at least kept to a minimum.

2.3 Arm posture

Try to keep your arm as close to your side as possible. Sit close to the patient and, where possible, get the patient to lie close to your side of the table or bed. Many patients attending for routine or investigative procedures (such as in obstetrics) are perfectly mobile and capable of adjusting their position as required. Make sure that you sit high enough to reach onto or, where necessary, over the patient. Standing might help you to adopt a better posture.

Where appropriate, move down the table or bed, rather than reaching behind you (Fig. 3). If necessary move the machine or its console. The new Aplio is smaller and lighter than its predecessor, so this is easier to do. Units fitted with a central pedal will make this even easier.

The shoulder joint has a very wide potential range of movement but, as with other joints, it is better when kept close to the neutral point of that range. Raising the arm, to the side or forwards, by more

Fig. 1: The narrow neck of this transducer allows it to be gripped without overstretching the hand.

Fig. 2: Change your grip to minimise wrist postures like this.

than about 45°, can restrict shoulder tendon blood flow and press the tendon against the underside of the acromioclavicular arch (linking the collar bone and shoulder blade). The arm is best kept in front of the line of the shoulders (sagittal plane), especially when elevated.

Some people have advocated the use of arm rests, supporting the arm in a raised position above the patient. While these might be beneficial in the short term, especially for those with existing shoulder problems, they are no substitute for working on getting the arm angle down.

Elevating the shoulder joint itself (this will occur at arm angles above about 60°) can lead to a risk of tension or compression in the nerves of the brachial plexus, especially if combined with adverse neck postures.

As well as the patient, the other area you will need to reach to on a regular basis will be the controls of the ultrasound machine. At times this will need a compromise between the need to reach the patient and the need to reach the controls. The Toshiba Aplio can help you with this. The position of the control console can be adjusted, to move the controls to a better location (Fig. 4) and, to give you even greater flexibility, many of the controls are re-programmable so you can decide, for example, where on the console you want important controls to be located (Fig. 5).

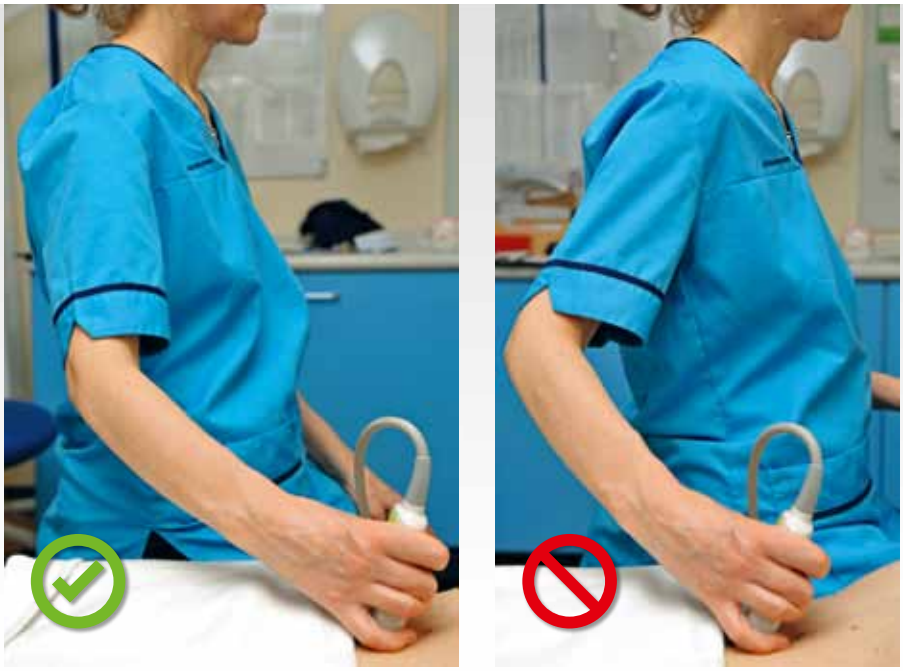

Fig. 3 a/b: Move yourself back, not just your arm, to avoid shoulder angles like this.

Fig. 4: Swivelling the console to the side can help avoid unnecessary stretching.

Fig. 5: Re-programme console controls to minimise repeated stretching or reaching.

As well as altering the controls on the console, moving the whole console can be helpful, especially in carrying out procedures where you would otherwise be stretching both ways at once.

2.4 Watch when you're looking

What do you most need to look at when you are doing a scan? It will usually be the ultrasound monitor screen (with the occasional glance at the patient). Are you sitting facing this screen, or is it to one side of you so that you have a twisted neck? Is it at the right height for your line of sight, or are you looking down at it, adding flexion to the neck rotation?

As with the console, the wide range of adjustability of the Aplio monitor helps you to get this right. Make sure that you have it at the right height, especially if you are standing to scan. Moving the screen sideways, towards the patient, can be a great help when carrying out procedures that require you to lean across (Fig. 6).

The neck vertebrae are the most mobile in the spine, but this mobility comes at a potential cost. Working for long periods with your neck twisted creates a low level tension within the neck muscles, which allows the gradual build-up of fatigue. Add shoulder elevation to one side and you have a recipe for neuromuscular tension problems. With age-related spinal degeneration in the mix, the scope for some gradual misalignment of bony structures in the neck is increased. You should take priority over the patient in viewing the screen. Showing any images to them is a courtesy not a primary requirement. Ideally, where this is customary (such as in pregnancy scans), a second screen will be provided. If it is not, freezing an image and then turning the screen to the patient is preferable to 'sharing' the screen while scanning. The monitor handle allows you to move the screen with one hand while you are scanning (and avoid finger smears on the screen (Fig.7).

2.5 Are you sitting comfortably?

Sitting is fundamentally bad for the human spine and trunk muscles. It distorts the shape of the spine, increases the pressure on the intervertebral discs, and increases the tension on the muscles, ligaments and other soft tissues which help to maintain the integrity of the spine – and that is when you are sitting upright. Add on the leaning and twisting which can also be associated with ultrasound procedures and the problems are compounded.

The first point to consider therefore is whether or not you would be better off standing – at least for some types of scan. Any procedure which requires a lot of twisting, leaning or stretching might well be better performed standing (but don't forget to get the patient to move for you when possible (Fig. 8). Sitting, particularly on a conventional chair 'holds' your pelvis in place, reducing your mobility compared to standing.

Even for simpler, more static procedures, much of the discomfort from sitting stems from spending prolonged periods with little or no movement of the muscles involved. If nothing else, standing up and moving about between patients (perhaps to fetch the next patient) is valuable exercise. If you are going to stand to work however, do make sure that you raise the bed or couch accordingly. Sometimes, having the patient sitting offers the best solution (Fig. 9).

Another potential benefit of standing to scan is that, depending on the design of the bed, it can solve the problem of where to put your knees. Much ultrasound work requires a compromise between your legs and arms. The arm 'works' best in front of the body and so, ideally, you would sit facing the patient. However, on a conventional chair your knees stick forwards and you won't be able to reach – so you sit sideways and reach out to the side. This solves the knee problem but, as a result, you will be twisting your neck or back (or both) to look towards the patient (as well as not being so good for your shoulder).

One compromise is the sit-stand chair. As the name suggests, it results in a posture somewhere between sitting (legs at 90°) and standing (legs straight). As a result, there is less knee in the way and it is easier to sit facing the patient. If you are not familiar with these chairs, try sitting on the edge of a desk. This will give you a good idea of the posture which results

Fig. 6: Setting the screen to one side can make it easier to view.

Fig. 7: Move the screen if you need to during a procedure.

from using such a chair. Of course you are sitting higher, and so the patient bed will need to be raised accordingly.

In some sit-stand chairs, the seat is relatively shallow (front to back). Other styles however are shaped, rather like a large bicycle saddle. This leads to another style of chair which can be useful, the saddle chair. Saddle chairs can be lower (more like a conventional chair) but you bestride it (as you would a saddle on a horse) with your thighs sloping downwards (again, as on a horse). This has the benefit of providing for a more 'open' trunk-thigh angle (good for the spine) and again meaning that your knees do not 'stick out' so far. However, the main advantage of this type of chair is the enhanced lateral mobility compared to a conventional chair. With a normal chair, the pelvis 'sits' firmly on the flat seat and any sideways leaning is predominantly achieved through lateral flexion of the spine (many are also slightly dished which increases

Fig. 8 a/b: Standing to scan can reduce the strain on the back and pelvis.

Fig. 9: Getting the patient to sit can help you achieve a good working posture.

Fig. 10: Using a saddle seat can reduce the strain on the low back and pelvis, especially when reaching across a patient.

Fig. 11: As the name suggests, the back rest on your chair is important. Make sure that it is correctly adjusted and use it when scanning.

this effect). In contrast, on a saddle chair the seat shape allows the user to tilt their pelvis as they lean, placing their foot more to the side at the same time to provide further stability (Fig. 10).

A similar sitting posture can be obtained from another style of chair, the kneeling chair. However, this style is NOT recommended for ultrasound work. The stabilisation provided by the knees make any leaning, turning or twisting required more of a problem and, unless you can guarantee working straight ahead of you, such chairs should not be used.

Some chairs used for ultrasound work are fitted with a backrest. In normal sitting, using the backrest (correctly adjusted for angle and support height) is an essential part of minimising the strain on the spine and back. Ultrasound work is no different and a good, well-designed backrest, properly adjusted can be a great help. Again, the design of the backrest should help you, not hinder you. With most conventional seating, the backrest is concave, curving round you to help hold you in an upright position. In ultrasound work this would be a hindrance as it would work against you when you need to lean to the side. In contrast a flat, or even slightly convex, backrest allows you to lean to the side while still leaning back against the backrest, still therefore providing you with some upper body support and taking some of the strain off your trunk muscles (Fig. 11).

The type of chair you choose will, to a certain extent, be a matter of personal preference. You should therefore take into account the design of bed or couch; the type of procedure you are mostly going to carry out; and the availability of different types of chair; in making your selection. However you sit, you should ideally sit high enough for your elbow height to be higher than the patient so you are not holding your arm up all the time.

2.6 Many hands make light work

One idea which some people have advocated is that of sitting facing the other way, allowing you to change hands, to scan with your left rather than your right (or vice versa). Intuitively this would, you would think, halve the strain on either side. It could be helpful but, the reality is unlikely to be so straightforward and I certainly wouldn't advocate it for everybody. Firstly, if you try this, bear in mind that it will initially place extra strain on the unaccustomed side. Think how much more strain you felt when you first started out carrying out scans. There is always more muscle tension with unaccustomed movements and actions and this will be the case here until you have learned them all over again with

How big a problem are MSDs?

As stated earlier, musculoskeletal disorders (MSDs) are a significant problem in most occupational groups and those carrying out ultrasound scans on a regular basis are no exception. Morton and Delf (2008) summarised the findings from more than ten surveys of ultrasound operators which reported prevalences of musculoskeletal pain and discomfort ranging from 63–89.7%. Although some of these surveys have methodological deficiencies, the overall message is clear, that musculoskeletal disorders are a serious problem amongst ultrasound practitioners (sonographers)[2].

The symptoms associated with MSDs can vary in nature and intensity. They can range from an occasional aching after an extended period of ultrasonography to severe, disabling pain. Neural symptoms can similarly vary from a vague numbness or tingling in the hand to severe loss of sensation (or again disabling neural pain radiating up or down the whole arm).

These symptoms are not restricted to one part of the body. For example, Wihlidal and Kumar (1997), in a study of sonographers in Alberta, Canada, reported the highest levels of symptoms affecting the shoulder girdle, neck, low back and forearms/hands. The exact order might vary between studies. Nevertheless a clear pattern emerges of these four areas of the body being those most affected.

What causes MSDs?

MSD symptoms occur widely in the adult population. For example, a UK-based survey of adults randomly selected from GP practices (Palmer et al, 2008) found that 46% reported arm pain in the previous 12 months. Of those with arm pain, nearly a quarter considered it to have been caused by their work, although interestingly only just over half of these had work which was considered to involve 'arm straining activities'. Clearly, it is not always easy to differentiate between provoking symptoms and causing any underlying problem.

Put simply, if you have a sore muscle for whatever reason, using that muscle will make it hurt, even though that use has not caused the soreness in the first place.

In practise however, the distinction is less important if trying to carry out your job leads to disabling pain. For example, in a study of sonographers which showed shoulder pain to be their most common problem, it was no surprise that work involving sustained shoulder abduction was most likely to aggravate symptoms (Muir et al, 2004).

Other researchers have carried out a more objective evaluation. For example, using a mixture of joint angle measurement and muscle electrical activity (emg), Village and Trask (2007) showed that, on average, sonographers spent almost 50% of their scanning time with their shoulders raised by more than 45° and had their neck bent forward, laterally or twisted more than 20° for an average of almost 40% of the scanning time. Data such as these can be compared objectively to factors believed to cause MSDs and can add to our understanding of causation (rather than aggravation). For example, objective emg data from the same study provided objective support for the perceived role of high grip force in hand/wrist problems amongst ultrasound practitioners.

the other hand. It will certainly slow you down, and might reduce the accuracy and precision with which you can work.

Secondly, not everybody finds such change easy. Apart from anything else, the habit of facing the patient's face or their feet (depending on how you have been trained) is hard to break. A third factor is the question of how 'handed' you are. Some people are very strongly one-handed (usually the right) and would find swapping over much more of a challenge.

3. Looking at the big picture

In summary, the muscles, ligaments, joints etc. of the human body are designed for movement. No matter how good a posture you adopt, it will become uncomfortable over time with little or no movement. How long a particular muscle will tolerate immobility will depend, to some extent, on the muscle in question, but also on the amount of effort demanded of it in maintaining that position.

Each body segment or joint has a 'neutral' posture: the position it adopts when relaxed. As a rough rule of thumb, the further you deviate from that posture the more load is imposed on the muscles maintaining that position. Think about how you sit and work. A twisted spine has more load on it than a straight spine; an arm hanging by your side creates less shoulder load than one at 45°; and so on. With this in mind, think about how you lay out and use your workplace. Move things (including patients) to a better position if possible, rather than compensating with awkward postures.

Where equipment can be adjusted, make full use of that facility. Where it can't be adjusted, can it be replaced by adjustable versions? This applies to your patient couch; your chair; and your ultrasound machine. As mentioned earlier, your Toshiba Aplio has a variety of adjustable features. However, these are only as good as you make them. Make sure you know how they work and how best to use them and the rest of your workplace to make your ultrasound scanning as comfortable and efficient as possible.

How your work is organised is also important. Although any ultrasound procedure can lead to problems, the different procedures do place more strain on different body parts and, where practicable, carrying out a variety of procedures during the day will allow parts of the body to recover at different times. Try to organise your work so you get frequent short breaks away from your ultrasound station, even if it is just to write up report notes or greet the next patient. The muscle movement

A number of studies have shown the prevalence of MSDs to increase with years of experience in ultrasound. For example, Evans et al (2009) reported pain while scanning to be most common amongst those over 50 with more than 20 years of experience. In many sonographers, age and years of experience go hand in hand, and it is easy to assume that all of this increased incidence with age can be blamed on their work. However, many MSDs have an age-related degenerative component. For example, by the age of 50, most people will have signs of degeneration of their cervical vertebrae, and a proportion will have symptoms as a result (such as pain or neural symptoms across the shoulder and down the arm) regardless of what they do for a living.

It should be also noted that Evans et al found nearly 15 % to have less than 6 years experience. Studies amongst other populations have shown individual differences in anatomy, to have a significant impact on the risk of subsequent injury. For example, specific aspects of the anatomy of the wrist have been related to carpal tunnel syndrome. In extreme cases, individuals have been known to develop symptoms (for example of tenosynovitis) within a week of starting work (although not, I hasten to add, in sonography).

Does it matter what type of ultrasound procedure I carry out?

Anecdotally, the type of scan undertaken is believed to be an influential factor in developing MSDs. However, although the differences in postures required suggests this to be a valid assumption, objective data presents a mixed picture. For example, Wihlidahl and Kumar (1997) demonstrated relationships between the type of postural 'shortcoming' (e.g. twisted neck, elevated shoulder) and the sites of symptoms. In turn, this might be expected to lead to specific procedures being more likely to result in more symptoms.

Similarly, Smith et al, (1997) reported an increased incidence of symptoms amongst those performing longer scans; or more scans per month. Again, it could be assumed that those procedures which routinely take longer would therefore be more likely to lead to problems.

However, Russo et al (2002) found few differences between those reporting pain and discomfort and those not, for different procedures, in terms of the frequency of scans performed per week or their typical duration.

The explanation is probably that the picture is, in reality, quite complex. Burnett and Campbell-Kyreghyan (2010) presented the results of a systematic assessment of various risk factors associated with different scan procedures. The authors found certain aspects to predominate in certain procedures. For example, average transducer force was much higher in DVT procedures than others whilst, in contrast, the average angle of wrist deviation was much higher in thyroid scans. The authors concluded that all of the investigated scan procedures involved injury risks, although the specific risk factors and their relative importance varied between scan types.

In all instances, the individual variation in values was usually extremely high. This high level of variation between individuals, even for the same procedure, suggests, in the words of the popular song, that the answer is probably: "It ain't what you do, it's the way that you do it".

associated with this will provide valuable active recovery. While you are about it, if you have a separate desk for writing-up, make sure that this is correctly set up as well.

Finally, this paper provides a basic guide to the ergonomics of ultrasound work. It is however inevitably general and you might benefit from more detailed advice, tailored to the working conditions you have to contend with. Your Toshiba clinical specialist can give some further help or, if you need to go for the hard stuff, a professional ergonomist (preferably one recognised by the Institute of Ergonomics and Human Factors in the UK, or the equivalent professional body in your country) should be able to help you.

Possible sources of expert help:
Institute of Ergonomics and Human Factors:
http://www.ergonomics.org.uk

International Ergonomics Association: Federated Societies:
http://www.iea.cc/03_member/Federated%20Societies.html

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Footnotes

[1] Some types of glove have been shown to cause allergies, especially with sustained use. Alternatives are available and you should liaise with relevant health and safety experts to select the most suitable type.

[2] Although most papers on this topic relate the problem to sonographers, other occupational groups or sub-groups can also be affected. Those reported in the literature include echocardiologists, vascular technologists, and sonologists.

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