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## **ABSTRACT**

**BACKGROUND:** Diagnostic ultrasound is traditionally and extensively used within the radiology department. However in recent years its use has expanded outside this traditional area into health professions such as physiotherapy, emergency medicine and anaesthesiology.

**PURPOSE:** The radiology community needs to be aware of the expansion of use of diagnostic ultrasound. This article starts this exploration in the health professions mentioned, however it is acknowledged that diagnostic ultrasound use goes beyond what is covered in this article. As diagnostic ultrasound is a user dependant modality and the outcome of an examination is largely influenced by the skill and experience of the operator,(Abu-Zidan, Freeman, & Mandavia) the radiology community should take a guiding role in its use, training and protocol development for health professionals.

**METHOD:** This article explores the literature on the use of diagnostic ultrasound within physiotherapy, emergency medicine and anaesthesiology. Literature was searched for on the databases Medline, Cinahl and Embase.

**RESULTS:** Diagnostic ultrasound is being used in health professions such as physiotherapy, where it is being used to provide biofeedback to patients on contraction of abdominal and pelvic floor muscles; emergency medicine, for the investigation of free fluid within the abdomen of a trauma patient and anaesthesiology, for the placement of catheters and nerve blocks.

**CONCLUSION:** As members of the radiology community are considered experts in the field, they need to take the lead to guide and mentor the other health professionals who are now using the modality. To be able to achieve this they must have an understanding of what these professions are using the modality for.

## **INTRODUCTION**

Diagnostic ultrasound has been traditionally used by radiologists and sonographers within radiology departments as a diagnostic tool for many years. However, over

recent years ultrasound imaging has been used by health professionals outside the traditional radiology department.(Abu-Zidan, et al., 1999; Australasian Society for Ultrasound in Medicine, 2008) Siegel(2001) attributes the widespread use and acceptance of ultrasound as an imaging technique to be due to the limited bioeffects of the modality. There are currently no restrictions on who can purchase and use a machine and there are an unknown number of users who do not have any connection with ultrasound societies or their registration bodies (Barnett, et al., 2000).

Diagnostic ultrasound does however fall within the scope of practice for emergency medicine and anaesthesiology.

Continued clinical training is required to build user confidence (Abu-Zidan, et al., 1999). Users must be able to acquire high quality images and then distinguish normal from abnormal. For this they must have knowledge of the mechanics and physics of the ultrasound machine, good hand – eye coordination and a thorough understanding of anatomy.(Frezza, Solis, Silich, Spence, & Martin, 1999) Ability to use diagnostic ultrasound “is often defined by the number of procedures a resident has performed with little or no regard for the performance itself (Frezza, et al., 1999, p.886).”

The Royal College of Radiologists in the UK give advice on ultrasound training stating that “operators are ethically and legally vulnerable if they have not been adequately trained, or use inappropriate equipment (Bodenham, 2006, p.416).” Cost of equipment and time in training appear to be the two main constraints on diagnostic ultrasound becoming mainstream within all physiotherapy, emergency medicine and anaesthesiology departments (Bodenham, 2006).

## **PHYSIOTHERAPY AND DIAGNOSTIC ULTRASOUND**

Physiotherapists have used therapeutic ultrasound, mostly to aid repair of soft tissue sporting injuries, for longer than diagnostic ultrasound has been used. They are now branching into diagnostic ultrasound particularly as a means of providing biofeedback to both the therapist and the patient particularly for rehabilitation and the feedback of a task being mastered by the patient. It is important that physiotherapists receive education and training in this modality and most physiotherapists are aware that successful training requires guidance from experts in the field and constant practice.(Taggart, et al., 2006) This is where the radiology community has an important role and needs to step in to the void and take charge of training and

guidance for this profession. Physiotherapists must always be aware of limitations in their experience and competence when using the modality. For physiotherapists the “advantages of ultrasound include its non-invasiveness, portability, relative inexpensiveness, lack of ionising radiation and its ability to be repeated as often as necessary making it particularly useful for the monitoring of treatment (Backhaus, et al., 2001, p.641).” The other advantage is that it can be used with the patient in any position, which allows for patient movement and assessment of muscle function in positions such as lying or standing. For physiotherapists the investment in equipment and training is costly, but as it is used more within the field for biofeedback, the benefits will expand and research in the field by physiotherapists will also increase. Diagnostic ultrasound is a benefit to the physiotherapy profession as well as the patient.(Frost & Clarke, 2004; Robertson & Baker, 2001; ter Haar, 1999, 2007)

The start of diagnostic ultrasound use among physiotherapists has been attributed to “the work of Dr Archie Young and colleagues at the University of Oxford in the 1980s (Whittaker, et al., 2007, p.434).” Physiotherapists use diagnostic ultrasound mostly for biofeedback looking for such things as changes in associated structures such as the bladder base, tissue deformation and movement; it can however also be used to assess muscle structure and behaviour and perform measurements of muscle thickness and bulk. It is used to evaluate muscles, related soft tissues and function during exercise and physical tasks. It has also been found useful in improving neuromuscular function by assisting the application of therapeutic interventions in patients for rehabilitation.(Whittaker, et al., 2007)

Physiotherapy use of diagnostic ultrasound has been defined as an emerging field with physiotherapists using the modality “to assist clients in ‘turning on’ specific muscle groups (visual biofeedback) (Frost & Clarke, 2004, p.10).” Biofeedback is used as a part of motor re-learning in which a patient learns what is required and how to perform a task. With time and practice, the aim is that gradually the task will become automatic and hopefully beneficial to the patients’ problem. Biofeedback is a teaching tool used to improve outcomes and helps the patient reliably perform the task. It allows for confirmation of a task being learnt and performed. If a task is not being performed correctly this can be detected and modifications made until the biofeedback shows that the task has been mastered. Biofeedback can be sensory and

physiotherapists do use palpation and electromyography as an indication of muscle change, however diagnostic ultrasound provides a visual feedback as well as an assessment tool as muscle bulk, patterns of motor activation and thickness measurements can be made which all indicate muscle activation.(Baessler, et al., 2008; Frost & Clarke, 2004; Teyhen, et al., 2005) Also, “the cross sectional area of a muscle is directly related to its ability to produce force (Pressler, Heiss, Buford, & Chidley, 2006, p.10).”

Physiotherapists are using diagnostic ultrasound to give the patient visual feedback on their transversus abdominis and spinal multifidus muscles. These muscles are seen to support and provide segmental stabilisation of the spine and therefore have an important role when treating patients for acute and chronic back pain. With just one episode of acute lower back pain both transversus abdominis and multifidus can stop activating, atrophy or show changes in the timing of activation. Physiotherapists train patients with lower back pain to perform an abdominal drawing in manoeuvre which involves activation of the multifidus and transversus abdominis muscles to stabilise the trunk and decrease symptoms associated with the pain.(Teyhen, et al., 2005) Studies have investigated the benefits of using diagnostic ultrasound for biofeedback with the multifidus muscle and found that the patients who had the biofeedback showed greater improvement and retained their improvement when compared to a control group (Van, Hides, & Richardson, 2006). Several studies have shown that diagnostic ultrasound biofeedback is a useful method of assisting patients to learn to contract muscles and can be reliably used in the clinical setting (Pressler, et al., 2006; Teyhen, et al., 2005; Van, et al., 2006). The modality is also good for biofeedback and assessment of the deep muscles of the neck, trunk and pelvis (Pressler, et al., 2006).

Another area where diagnostic ultrasound is used by physiotherapists is for biofeedback of a pelvic floor muscle contraction. This contraction is taught to patients who present with urinary incontinence. Diagnostic ultrasound has advantages over traditional techniques and devices that are used by physiotherapists for this type of assessment such as palpation and perinometry.(Dietz, Jarvis, & Vancaillie, 2002) It is non invasive, easily performed, gives quick biofeedback, is convenient and is understood by the patient (Baessler, et al., 2008; Dietz, et al., 2002). Patients who present with pelvic floor muscle dysfunction are trained to perform a pelvic floor

muscle contraction which elevates the pelvic floor. This elevation lifts the urinary bladder, specifically the bladder base and neck, this elevation can be seen, assessed and measured using transperineal and transabdominal ultrasound. Information about the supporting function of the pelvic floor muscles during manoeuvres such as sneezing, coughing and valsalva can also be assessed by imaging the bladder.(Whittaker, Thompson, Teyhen, & Hodges, 2007)

## **DIAGNOSTIC ULTRASOUND IN THE EMERGENCY DEPARTMENT**

Diagnostic ultrasound can be used by doctors within the emergency department on trauma patients, to detect free fluid within the abdomen, haemoperitoneum; or around the heart, haemopericardium. Studies have shown that ultrasound is not widely used within the emergency department within Australia however there is extensive literature on the topic.(Abu-Zidan, et al., 1999) The words ‘compact, portable and user friendly’ were used by Rozycki, Ochsner, Jaffin, & Champion(1993) who also commented on the quick availability of results and the reduced cost and non invasiveness of the modality when compared to modalities of similar accuracy. It was recognised that quality assurance and credentialing guidelines are required for use. Every patient should receive access to the best quality care twenty four hours a day however not all radiology departments offer such an extensive service. If the emergency department doctor was trained to use the modality it might then be available all the time, resulting in better patient care. It has been shown that emergency doctors can produce the same results as trained surgeons and radiologists when performing these examinations.(Abu-Zidan, et al. 1999)

Many emergency departments have had trouble gaining hospital approval to perform diagnostic ultrasound due to a “lack of publicised information regarding the goals of such use, the scope of emergency physician ultrasound privileges, emergency physician ultrasound credentialing criteria and emergency department ultrasound quality improvement plans (Tandy & Hoffenberg, 1997, p.367).” The main reason for introducing doctor performed ultrasound to the emergency department is to improve the quality of patient care. The benefits in the emergency department are time savings, improvement in patient flow, less reliance on call in services, immediate feedback, minimal patient transport, empowering staff providing staff satisfaction, staff personal growth and currency and finally, a decreased cost of providing care.(Tandy & Hoffenberg, 1997)

The initial and most common examination performed by doctors in the emergency department on trauma patients is called the FAST – Focused Assessment for the Sonography of Trauma or Focused Abdominal Sonography for Trauma (Australasian College for Emergency Medicine, 2008; Freitas, Frangos, & Frankel, 2006; Glazebrook, Manahan, & Chater, 2005; Scalea, et al., 1999). The FAST exam is used to identify evidence of injury (Scalea, et al., 1999). FAST examinations have been shown to improve diagnostic accuracy and optimise patient care (Lapostolle, et al., 2006). Diagnostic ultrasound can be the initial modality used to detect haemoperitoneum in patients with blunt abdominal trauma as peritoneal lavage is invasive and CT scans are costly (Rozycki, Ballard, Feliciano, Schmidt, & Pennington, 1998). It is a focused, brief and interactive examination used to answer a small number of questions and allows for a rapid diagnosis at the patients' bedside simultaneously with other critical care procedures. It is reported to be reliable and rapid in demonstrating abdominal free fluid and has the potential to decrease the time a patient spends in the emergency department and increases their satisfaction with the service provided. It is important that doctors are exposed to the modality early in their training so it becomes a routine part of their clinical practice.(Han, Rozycki, Schmidt, & Feliciano, 1996)

The FAST exam should assess four regions of the body, the pericardial, perihepatic, perisplenic and pelvic regions. The scan has been proven to detect major hepatic, splenic and renal injuries by detecting free fluid in these four regions of the body. It must be remembered that in the unstable patient, the goal of FAST is to rapidly determine whether shock is attributable to haemoperitoneum or haemopericardium.(Scalea, et al., 1999)

FAST also has limitations which must be taken into consideration and any emergency doctor using FAST should be made aware of these. As with all ultrasound examinations, patient habitus and abdominal gas, ileus or surgical emphysema can limit visualisation; also the technique used and the skill of the operator can all pose limitations.(Brown, Sirlin, Hoyt, & Casola, 2003; Radwan & Abu-Zidan, 2006) While FAST can rule in abdominal haemorrhage, it cannot totally exclude a condition as small volumes of blood may be missed, the blood may not have pooled in dependant areas due to the changing of the patient position, or the bleeding organ may

only be bleeding slowly. While FAST can detect free fluid “it can not differentiate between blood, urine, bile or ascites (Radwan & Abu-Zidan, 2006, p.188).” “Up to 29% of abdominal injuries may be missed if blunt trauma victims are evaluated with admission FAST as the sole diagnostic tool (Chiu, et al., 1997, p.617).”

The radiology department should expect to be central in the training, development of imaging protocols and mentoring of emergency department use of diagnostic ultrasound. There should be close cooperation between both departments with radiology being the gold standard in difficult imaging situations where formal imaging studies should be performed. It must be remembered that emergency scans performed in an emergency department such as FAST, are goal oriented and not as detailed as abdominal scans performed by the radiology department. This limited, goal oriented approach helps with the learning and interpretation process as the volume of information to learn is reduced as are the possible pathologies that can be detected.(Burnett & Nicholson, 1999)

A concern in the literature is that diagnostic ultrasound use in the emergency department will decrease the referrals to the radiology department. In fact, Heller, Melanson, Patterson, & Raftis(1999) found that during the ultrasound training programme, referrals actually increased. While Jacoby et al.(2003) found the same thing initially; they found that after an initial period of several years, referrals declined to levels below those before the training programme was implemented. Other studies state that diagnostic ultrasound in the emergency department will not replace that within the radiology department (Abu-Zidan, et al., 1999). It must be remembered that it is being used to improve and expedite patient care and if a close alliance between the two departments is formed, all such fears should be alleviated.

There is a difference between demonstrating normality and providing quality. It is harder to rule out a diagnosis than it is to confirm one. “Casualty based ultrasound can be a triage tool – operating on simple parameters offered by many staff or it can offer a service requiring intense training and offering high level answers. It should be appreciated that if the first option is taken the place of specialist ultrasound remains (Burnett & Nicholson, 1999, p.251).”

## **DIAGNOSTIC ULTRASOUND IN ANAESTHESIOLOGY**

Baumgarten(2007) suggests that anaesthetists might use diagnostic ultrasound for guidance with nerve blocks, bladder volume assessment, “detection of cardiac tamponade, pneumothorax, severe hypovolaemia, and pleural effusion (Baumgarten, 2007, p.1292).” It is also suggested that it might increase the speed with which conditions are diagnosed thereby saving lives. The modality could improve efficiency and patient satisfaction for example in patients with difficult venous access. “By helping us discharge patients more rapidly, ultrasound could produce significant cost savings.....we in anaesthesia must master ultrasound skills so that our specialty can join the ultrasound revolution (Baumgarten, 2007, p.1292).”

In some clinical cases anaesthetists can use peripheral nerve blocks instead of a general anaesthesia. This involves injection of local anaesthetic around a nerve. Peripheral nerve blocks however pose challenges and can result in failures. This can mostly be attributed to the fact that not all anatomy is the same as that found in the textbook; anatomical variation does exist. Thus anaesthetists using surface landmarks and textbook anatomy can result in block failure. Also in some cases, nerve stimulation may not occur even if the needle is in the correct position or injection into the nerve itself rather than around it can occur.(Sites, et al., 2008)

The benefits of using diagnostic ultrasound for peripheral nerve blocks are that the anaesthetist can miss surrounding structures such as vessels and organs, thus reduce injury. The target nerve can be found, its size and depth, the needle can be localised and its advancement into the correct position monitored and corrected and the spread of the local anaesthetic can be seen. The success rate of peripheral nerve blocks can be improved, the procedure time can be shortened, the onset of the block can be faster, the effective dose of anaesthetic can be reduced and complications can be decreased which ultimately improves patient satisfaction.(Partownavid, 2009; Rubin, Sullivan, & Sadhasivam, 2009; Sites, et al., 2008) In children, higher success rates and longer duration of the blocks has been reported (Rubin, et al., 2009).

Limitations cited in the literature for use of diagnostic ultrasound for peripheral nerve blocks included the learning curve when using the modality, the training required, the cost and availability of the equipment and artefact generation (Marhofer & Chan, 2007; Partownavid, 2009; Sites, et al., 2008). While diagnostic ultrasound has been

reported to have an increase in success rates and a shortening in the time taken to perform a peripheral nerve block, “unfortunately success that rivals the near 100% rate enjoyed by general anaesthesia has not yet been realised (Sites, et al., 2008, p.465).”

For neuraxial blocks in children ultrasound has been found to visualise the spinal cord and dura and as such help lower the risk of trauma to the spinal cord (Rubin, et al., 2009). It has also been shown to improve needle insertion accuracy in epidural anaesthesia in adults (Tran, et al., 2009). It can be used as a guidance tool and “can be used to estimate the midline depth to the epidural space (Tran, et al., 2009, p.661)” as well as counting the intervertebral levels (Furness & Reilly, 2002).

Another area of importance in anaesthesiology is for the insertion of central venous catheters. These are commonly inserted in the internal jugular, subclavian or femoral vein for haemodynamic monitoring, intravenous delivery of blood products and drugs such as giving vasopressors and cytotoxic drugs, haemodialysis, blood sampling, total parenteral nutrition, cardiac pacemaker placement and management of perioperative fluids.(Muhm, 2002; National Institute for Clinical Excellence, 2002) They may also be inserted in “patients undergoing cancer treatment, dialysis or coronary or other major surgery (National Institute for Clinical Excellence, 2002, p.2)” or the critical care patient. The traditional technique used for central venous access involves surface anatomical landmarks and knowing the anatomical position of the vein in relation to the artery (Gann & Sardi, 2003; Muhm, 2002; National Institute for Clinical Excellence, 2002). It is really a blinded technique (Gann & Sardi, 2003).

Complications of central venous catheterisation are generally low (Gann & Sardi, 2003). “They depend on the experience of the operator, the access site chosen, the condition of the patient, the presence of atypical vascular anatomy, the coagulation status of the patient and previous catheterisation (Muhm, 2002, p.1373).” The common complications however do have the “potential for morbidity and mortality (Hall & Russell, 2005, p.1).” They include puncture of the artery, arteriovenous fistula, pneumothorax, haemothorax, cardiac tamponade, haematoma, poor catheter position, nerve injury, multiple unsuccessful attempts which delay treatment, inability to cannulate and death (Gann & Sardi, 2003; Muhm, 2002; National Institute for Clinical Excellence, 2002). Difficulty in cannulation can occur in patients with

obesity, short and broad necks, scarring from surgery or radiation treatment, goitre, tumours, lumps, previous difficult insertion and a previous central venous catheter due to an increased risk of haematoma or thrombus (Hall & Russell, 2005; National Institute for Clinical Excellence, 2002).

Many of the above mentioned complications can be avoided through the use of diagnostic ultrasound as it allows visualisation of the vein and surrounding anatomical structures so anatomical variants or thrombus within the vein can be detected, which can change patient management and catheterisation technique (Gann & Sardi, 2003; Hall & Russell, 2005; National Institute for Clinical Excellence, 2002). The needle can also be seen so its passage can be guided into the correct position past structures such as the artery, nerve and lung (Gann & Sardi, 2003; Hall & Russell, 2005; National Institute for Clinical Excellence, 2002). It has the potential to reduce complications such as puncture of the artery, artery haematoma, pneumothorax, haemothorax and infection (Karakitsos, et al., 2006; National Institute for Clinical Excellence, 2002). It can reduce the time it takes to access the vein and reduce the number of attempts or passes to access the vein (Hall & Russell, 2005; Karakitsos, et al., 2006). It is reported as being a timely, risk and complication minimising and success maximising technique (Gann & Sardi, 2003).

National Institute for Clinical Excellence(2002) recommend diagnostic ultrasound use for insertion of central venous catheters in elective and emergency situations. They also recommend training in the modality to achieve competence. There is a learning curve in mastering the technique however its use is reported as being widespread (French, Raine-Fenning, Hardman, & Bedforth, 2008; Hall & Russell, 2005).

Bodenham(2006) discusses the use of diagnostic ultrasound by anaesthetists in the UK. He suggests that while departments have purchased equipment to meet guidelines such as those for central venous access, no formal training or system accreditation is happening. There is a lack of guidance in the UK from relevant bodies on “the necessary equipment, knowledge base, skills or practical experience that are required before using such technology independently (Bodenham, 2006, p.414).” Clinical pressures exist for the modality to be used to improve diagnostic and interventional procedures. “There is a danger that the important issues of equipment maintenance, calibration and replacement/upgrading are ignored when

departments other than radiology make a one off purchase (Bodenham, 2006, p.415).” “If ultrasound is to become an integral part of regional anaesthesia, future guidelines and teaching curricula must be established for proper training.....At the present time, teaching resources for ultrasound-guided nerve blocks are limited (Marhofer & Chan, 2007, p.1268).” The radiology community should take the lead to guide and mentor anaesthetists in the use of this technology and work together to produce formal training and system accreditation.

## **CONCLUSION**

Diagnostic ultrasound use is expanding outside the traditional radiology department. Professions such as physiotherapy, emergency medicine and anaesthesiology have found advantage in using the modality within their practice. All professions are struggling with issues such as cost, training, skill maintenance and support. As awareness of the modality increases its use and acceptance within the health professions will also increase.

Diagnostic ultrasound is well known to be a user dependant modality in that the outcome of the study is influenced by the skill and experience of the operator (Abu-Zidan, et al., 1999). Professions that do use the equipment also need to put time and resources into training. Lack of training in the modality or misuse of the modality could result in both ethical and legal vulnerabilities.(Bodenham, 2006) The role of the radiology community has therefore also expanded outside the traditional radiology department. As the experts in the field, the radiology community has the skill and experience and should lead the training, guidance and support of other healthcare professionals as users of this evolving technology. This can only be done however if there is an understanding of the use of this modality by these health professions.

## **REFERENCES**

- Abu-Zidan, F. M., Freeman, P., & Mandavia, D. (1999). The First Australian Workshop on Bedside Ultrasound in the Emergency Department. *New Zealand Medical Journal*, 112(1094), 322-324.
- Australasian College for Emergency Medicine (2008). *Policy on credentialling for ED ultrasonography: trauma examination and suspected AAA*. Retrieved 8th December, 2008, from [www.acem.org.au](http://www.acem.org.au)
- Australasian Society for Ultrasound in Medicine (2008). *Policies and statements*. Retrieved 8th December, 2008, from [www.asum.com.au](http://www.asum.com.au)

- Backhaus, M., Burmester, G.-R., Gerber, T., Grassi, W., Machold, K. P., Swen, W. A., et al. (2001). Guidelines for Musculoskeletal Ultrasound in Rheumatology. *Annals of the Rheumatic Diseases*, 60, 641-649.
- Baessler, K., Schussler, B., Burgio, K. L., Moore, K. H., Norton, P. A., & Stanton, S. L. (2008). *Pelvic Floor Re-Education Principles and Practice* (second ed.). London: Springer.
- Barnett, S. B., Ter Haar, G. R., Ziskin, M. C., Rott, H. D., Duck, F. A., & Maeda, K. (2000). International Recommendations and Guidelines for the Safe use of Diagnostic Ultrasound in Medicine. *Ultrasound in Medicine and Biology*, 26(3), 355-366.
- Baumgarten, R. K. (2007). The Real Ultrasound Revolution. *International Anesthesia Research Society*, 104(5), 1292.
- Bodenham, A. R. (2006). Editorial II: Ultrasound Imaging by Anaesthetists: Training and Accreditation Issues. *British Journal of Anaesthesiology*, 96(4), 414-417.
- Brown, M. A., Sirlin, C. B., Hoyt, D. B., & Casola, G. (2003). Screening Ultrasound in Blunt Abdominal Trauma. *Journal of Intensive Care Medicine*, 18(5), 253-260.
- Burnett, H. C., & Nicholson, D. A. (1999). Current and Future Role of Ultrasound in the Emergency Department. *Journal of Accident and Emergency Medicine*, 16, 250-254.
- Chiu, W. C., Cushing, B. M., Rodriguez, A., Ho, S. M., Mirvis, S. E., Shanmuganathan, K., et al. (1997). Abdominal Injuries Without Hemoperitoneum: a Potential Limitation of Focused Abdominal Sonography for Trauma (FAST). *The Journal of Trauma Injury, Infection and Critical Care*, 42(4), 617-625.
- Dietz, H. P., Jarvis, S. K., & Vancaillie, T. G. (2002). The Assessment of Levator Muscle Strength: a Validation of Three Ultrasound Techniques. *International Urogynecology Journal*, 13, 156-159.
- Freitas, M. L., Frangos, S. G., & Frankel, H. L. (2006). The Status of Ultrasonography Training and Use in General Surgery Residency Programs. *Journal of the American College of Surgeons*, 202(3), 453-458.
- French, J. L. H., Raine-Fenning, N. J., Hardman, J. G., & Bedford, N. M. (2008). Pitfalls of Ultrasound Guided Vascular Access: the Use of Three/Four-Dimensional Ultrasound. *Anesthesia* 63, 806-813.
- Frezza, E. E., Solis, R. L., Silich, R. J., Spence, R. K., & Martin, M. (1999). Competency-Based Instruction to Improve the Surgical Resident Technique and Accuracy of the Trauma Ultrasound. *The American Surgeon*, 65(9), 884-888.
- Frost, N., & Clarke, J. (2004). Ultrasound for Biofeedback in Physiotherapy. *Sound Effects*, 4, 10-13.

- Furness, G., Reilly, M. P., & S, K. (2002). An Evaluation of Ultrasound Imaging for Identification of Lumbar Intervertebral Level. *Anesthesia*, 57, 277-280.
- Gann, M., & Sardi, A. (2003). Improved Results Using Ultrasound Guidance for Central Venous Access. *American Surgeon*, 12, 1104-1107.
- Glazebrook, R., Manahan, D., & Chater, A. B. (2005). Evaluation of an Ultrasound Program (Intermediate Obstetric and Emergency Medicine) for Australian Rural and Remote Doctors. *Australian Journal of Rural Health*, 13(5), 295-299.
- Hall, A. P., & Russell, W. C. (2005). Toward Safer Central Venous Access: Ultrasound Guidance and Sound Advice. *Anaesthesia*, 60, 1-4.
- Han, D. C., Rozycki, G. S., Schmidt, J. A., & Feliciano, D. V. (1996). Ultrasound Training During ATLS: an Early Start for Surgical Interns. *The Journal of Trauma Injury, Infection and Critical Care*, 41(2), 208-213.
- Heller, M., Melanson, S., Patterson, J., & Raftis, J. (1999). Impact of Emergency Medicine Resident Training in Ultrasonography on Ultrasound Utilization. *American Journal of Emergency Medicine*, 17(1), 21-22.
- Jacoby, J. L., Melanson, S., Eberhardt, M., Kasarda, D., Reed, J., & Heller, M. B. (2003). Short and Long Term Effects of Emergency Medicine Ultrasound on Formal U/S Utilization: A Decade of Experience. *Academic Emergency Medicine*, 10(5), 487.
- Karakitsos, D., Labropoulos, N., De Groot, E., Patrianakos, A. P., Kouraklis, G., Poularas, J., et al. (2006). Real-Time Ultrasound Guided Catheterization of the Internal Jugular Vein: a Prospective Comparison to the Landmark Technique in Critical Care Patients. *Critical Care*, 10(6), R162.
- Lapostolle, F., Petrovic, T., Lenoir, G., Catineau, J., Galinski, M., Metzger, J., et al. (2006). Usefulness of Hand-Held Ultrasound Devices in Out-of-Hospital Diagnosis Performed by Emergency Physicians. *American Journal of Emergency Medicine*, 24(2), 237-242.
- Marhofer, P., & Chan, V. W. S. (2007). Ultrasound-Guided Regional Anesthesia: Current Concepts and Future Trends. *Anesthesia and Analgesia*, 104(5), 1265-1269.
- Muhm, M. (2002). Ultrasound Guided Central Venous Access is Useful for Beginners, in Children and When Blind Cannulation Fails. *British Medical Journal*, 325, 1373-1374.
- National Institute for Clinical Excellence (2002). *Guidance on the Use of Ultrasound Locating Devices for Placing Central Venous Catheters (NICE Technology Appraisal, No. 49)*. London: NICE.
- Partownavid, P. (2009). Ultrasound-Guided Peripheral Nerve Block. *American Journal of Therapeutics*, 16, 304-312.

- Pressler, J. F., Heiss, D. G., Buford, J. A., & Chidley, J. V. (2006). Between-Day Repeatability and Symmetry of Multifidus Cross-Sectional Area Measured Using Ultrasound Imaging. *Journal of Orthopaedic and Sports Physical Therapy*, 36(1), 10-18.
- Radwan, M. M., & Abu-Zidan, F. M. (2006). Focussed Assessment Sonography Trauma (FAST) and CT Scan in Blunt Abdominal Trauma: Surgeon's Perspective. *African Health Sciences*, 6(3), 187-190.
- Robertson, V. J., & Baker, K. G. (2001). A Review of Therapeutic Ultrasound: Effectiveness Studies. *Physical Therapy*, 81(7), 1339-1350.
- Rozycki, G. S., Ballard, B., Feliciano, D. V., Schmidt, J. A., & Pennington, S. D. (1998). Surgeon-Performed Ultrasound for the Assessment of Truncal Injuries: Lessons Learned From 1540 Patients. *Annals of Surgery*, 228(4), 557-567.
- Rozycki, G. S., Ochsner, M. G., Jaffin, J. H., & Champion, H. R. (1993). Prospective Evaluation of the Surgeons' Use of Ultrasound in the Evaluation of Trauma Patients. *Journal of Trauma-Injury Infection and Critical Care*, 38, 516-527.
- Rubin, K., Sullivan, D., & Sadhasivam, S. (2009). Are Peripheral and Neuraxial Blocks With Ultrasound Guidance More Effective and Safe in Children? *Pediatric Anesthesia*, 19, 92-96.
- Scalea, T. M. M. D., Rodriguez, A. M. D., Chiu, W. C. M. D., Brenneman, F. D. M. D., Fallon, W. F. J. M. D., Kato, K. M. D., et al. (1999). Focused Assessment with Sonography for Trauma (FAST): Results from an International Consensus Conference. *The Journal of Trauma Injury, Infection and Critical Care*, 46(3), 466-472.
- Siegel, R. J. (2001). Therapeutic Ultrasound, Part I. *Echocardiography*, 18(3), 211-212.
- Sites, B. D., Spence, B. C., Gallagher, J., Beach, M. L., Antonakakis, J. G., Sites, V. R., et al. (2008). Regional Anesthesia Meets Ultrasound: a Specialty in Transition. *Acta Anaesthesiology Scandanavia*, 52, 456-466.
- Taggart, A., Filippucci, E., Wright, G., Bell, A., Cairns, A., Meenagh, G., et al. (2006). Musculoskeletal Ultrasound Training in Rheumatology: The Belfast Experience.[see comment]. *Rheumatology*, 45(1), 102-105.
- Tandy, T. K., & Hoffenberg, S. (1997). Emergency Department Ultrasound Services by Emergency Physicians: Model for Gaining Hospital Approval. *Annals of Emergency Medicine*, 29(3), 367-374.
- ter Haar, G. (1999). Therapeutic Ultrasound. *European Journal of Ultrasound*, 9, 3-9.
- ter Haar, G. (2007). Therapeutic Applications of Ultrasound. *Progress in Biophysics and Molecular Biology*, 93, 111-129.
- Teyhen, D. S., Miltenberger, C. E., Deiters, H. M., Del Toro, Y. M., Pulliam, J. N., Childs, J. D., et al. (2005). The Use of Ultrasound Imaging of the Abdominal

Drawing - in Maneuver in Subjects With Low Back Pain. *Journal of Orthopaedic and Sports Physical Therapy*, 35(6), 346-355.

Tran, D., Kamani, A. A., Lessoway, V. A., Peterson, C., Hor, K. W., & Rohling, R. N. (2009). Preinsertion Paramedian Ultrasound Guidance for Epidural Anesthesia. *Anesthesia and Analgesia*, 109(2), 661-667.

Van, K., Hides, J. A., & Richardson, C. A. (2006). The Use of Real-Time Ultrasound Imaging for Biofeedback of Lumbar Multifidus Muscle Contraction in Healthy Subjects. *Journal of Orthopaedic and Sports Physical Therapy*, 36(12), 92-925.

Whittaker, J. L., Teyhen, D. S., Elliott, J. M., Cook, K., Langevin, H. M., Dahl, H. H., et al. (2007). Rehabilitative Ultrasound Imaging: Understanding the Technology and its Applications. *Journal of Orthopaedic and Sports Physical Therapy*, 37(8), 434-449.

Whittaker, J. L., Thompson, J. A., Teyhen, D. S., & Hodges, P. (2007). Rehabilitative Ultrasound Imaging of Pelvic Floor Muscle Function. *Journal of Orthopaedic and Sports Physical Therapy*, 37(8), 487-498.