

## **ULTRASOUND TRANSDUCER DESIGNS**

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The design of hand-held tools has evolved over the years from individually owned tools to instruments that have to fit a number of different workers. For centuries, tools were constructed to fit an individual craftsman's physical dimensions. The individual's extremities determined the dimensions and shape of the tool, which the worker took with him from job to job. <sup>(1)</sup> The significance of a tool that was a good fit for the user was recognized early in man's evolution. This is evidenced by the progression of axe handle designs which demonstrate that man attempted to improve the interface between himself, his tools, and the task for which the tool was used. <sup>(2)</sup> Tools that are not customized to each worker can lead to a loss in the transmission of power, unbalanced pressure distribution, and can impact work efficiency. <sup>(1)</sup> Poor tool design can ultimately lead to occupational musculoskeletal injury. Today's work methods have resulted in tools that have multiple uses, as well as multiple users. Therefore, a tool design has to accommodate the physical dimensions of the majority of users.

This is especially true of ultrasound transducers. Unlike the fixed components of the ultrasound system, transducers are somewhat freely moveable and require a certain amount of force and upper extremity motion to use. It is clearly impractical and cost prohibitive for multiple transducers to be designed to fit each individual sonographer, as well as every exam requirement.

Some guidelines for hand-tool design include the following: <sup>(3)</sup>

- Handle shape should preserve a neutral wrist position
- Tool weight should be minimized
- Center of gravity of the tool should align with the center of the hand
- Design should facilitate use with either hand
- Handle shape should be cylindrical or oval with a width that accommodates both male and female users

Aside from these design recommendations, there are additional factors that enter into the design of transducers and include type of exam, use of the transducer by both left and right-handed workers and how sonographers prefer to hold the transducer. Some sonographers prefer to hold the transducer higher near the cable and some prefer to hold it near the transducer face.



(Figure 1 Various ways that sonographers hold the transducer)

The insertion of the cable into the transducer has to be considered, since an off-center insertion might reduce torque on the user's forearm but might also interfere with some applications.

New exam types, such as endocavitary and intraluminal exams, have necessitated innovative transducer designs with longer, narrow handles. The increasing use of ultrasound for guidance during interventional procedures brings up other design considerations, such as biopsy guides on the transducer and ease of manipulation of the transducer during the procedure. The shape of the transducer and the material with which it is constructed must be easy and quick to clean. And, finally, the design must be considered from the patient's perspective. There should be no sharp edges and the transducer face should provide good, and comfortable, contact with the patient's body.

The development of any new product requires a business plan, a needs analysis and a feasibility study. From that point, a new transducer design can take from 6 to 12 months to develop. The process involves developing a number of prototypes, each with slight design differences. These prototypes are then evaluated by various users who provide feedback and allow the designers to see

how they are used in practice. In recent years, the transducer design process has focused more on ergonomics with an emphasis on reducing the weight of the transducer and its cable. One transducer design encourages a more comfortable palmar grip and has an off-set cable insertion, which is intended to reduce the torque on the sonographer's forearm caused by the cable. In addition, the casing on this transducer is composed of elastomere which greatly increases its "gripability", thus greatly reducing the risk for musculoskeletal injury related to holding the transducer. (Figure 3)

Just as we have seen ultrasound systems evolve from articulated arm scanners to real-time systems, we have seen transducers change in size, shape and weight. The design focus is now on volume acquisition, 3D and 4D transducers that have faster image acquisition times, position sensors, and easier imaging of difficult patients. Although wireless transducers have raised some interest, among both manufacturers and imaging professionals, they have a number of limitations. The lack of the transducer cable eliminates torque on the user's wrist caused by how the cable inserts into the transducer case and removes the need for cable management. However, if the transducer is not connected to the ultrasound system, it can be misplaced or lost. In addition without the cable, the transducer has to receive power from an internal battery which increases its weight. This raises the concern of transferring the risk for occupational injury associated with the cable to risks associated with increased transducer weight or size. But the main barrier to overcome in the development of wireless transducers is the massive amount of data that has to be transferred from the transducer to the ultrasound system. A revolutionary finger mounted ultrasound transducer is being developed that addresses both ergonomic issues and new ultrasound uses. The transducer is worn on the operator's finger and leverages the positional control necessary for ultrasound guided biopsies and vascular access. The connector and cable are worn on the arm and hip, thus eliminating torque on the wrist.

Regardless of the amount of research and the changes that have been incorporated into transducer designs, the most important component in the user-machine interface is the sonographer. The shape of the transducer should promote a palmar grip using the entire hand; however, the sonographer must adjust his or her grip so that the hand is comfortable and the transducer is not being held using the small muscles of the fingers.



(Figure 2. Examples of “pinch” grips” and palmar grip)

By supporting the scanning arm, a sonographer can reduce stress to the hand and forearm caused by the weight of a transducer. Any hand tool should be used with the arms held close to the body. Therefore, sonographers should position their patients to reduce arm abduction and reach while scanning. The design of a tool is only effective if it is used in an ergonomic manner.

Transducers will continue to evolve and new applications will continue to be identified. It is important, therefore, that imaging professionals grow into those changes and be creative and flexible in how they use their tools.



(Figure 3. Off-set cable reduces torque on the forearm. The transducer shape promotes a palmar grip. Photo courtesy of Siemens.)



(Figure 4. Transducer design has a comfortable width and promotes a palmar grip. Photo courtesy of Zonaare)



(Figure 5. Photo courtesy of Sonosite)



(Figure 6. Finger mounted transducer. Photo courtesy of Blacktoe Medical, Inc.)

1) Strasser, H; Assessment of the Ergonomic Quality of Hand-Held Tools and Computer Input Devices; IOS Press, 2007.

2) ErgoWeb; [www. Ergoweb.com](http://www.Ergoweb.com)

3) Salvendy, G; Handbook of Human Factors and Ergonomics, 2<sup>nd</sup> ed., John Wiley & Sons, Inc., 1997.