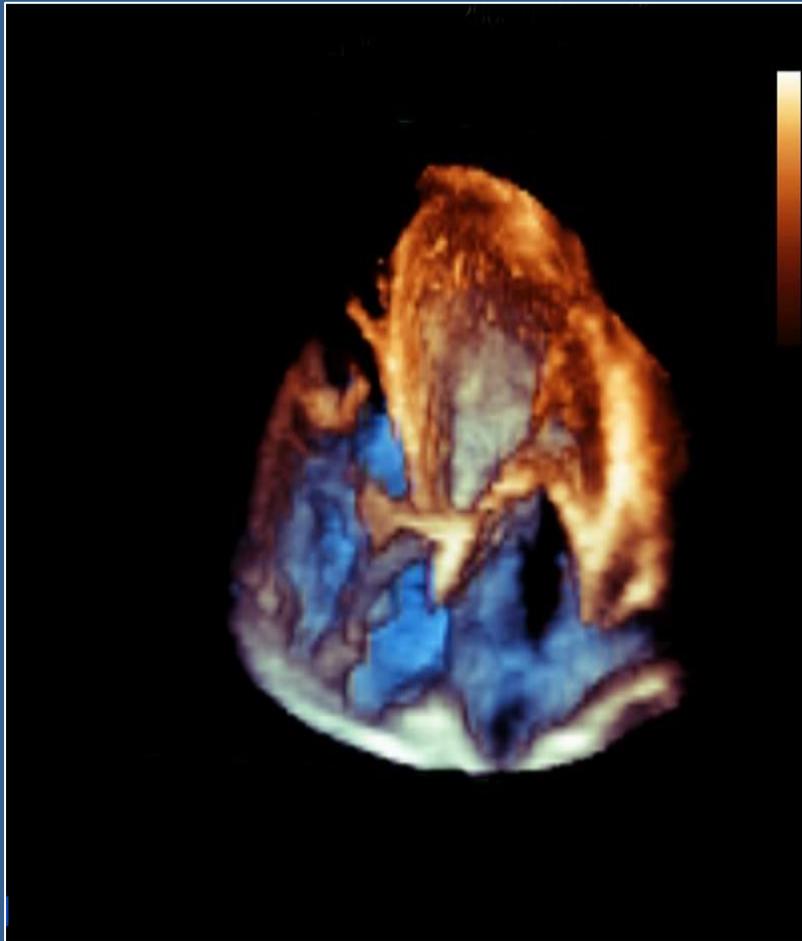


On the Proper Care of a Transesophageal (TEE) Probe

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INTRODUCTION

Transesophageal echocardiography (also referred to in this paper as TEE) has become the standard of care for various cardiac related clinical applications and is used in the echo laboratory, outpatient settings, as well as the operating room. The clinical dependence on the proper operation of these probes is increasingly expanding due to both the clinical utility of TEE and significant technological advancements in transducer design, specifically and recently with 2D matrix arrays that provide high-resolution 4D volumetric images. TEE probes are often used in the most demanding clinical environments and are frequently exposed to many different hazards that can result in damage to this important and expensive probe. In fact, the proper care and regular testing of TEE probes are the key determinants relative to the overall level of operating expenses related to the ultrasound systems in the echo department. Empirically derived data over the last 10 years has shown that approximately 70% of ultrasound service calls turn out to be, in some manner, probe related. Multiple published studies have also shown that improperly functioning probes can negatively impact the clinical results of the ultrasound examination¹⁻³. However, almost all TEE probe failures, when discovered early enough, can be repaired in a safe and efficacious manner, potentially saving the echocardiography department tens-of-thousands of dollars per year in operating expense. This white paper is designed to present the clinical end user, as well as those responsible for the care of the TEE probes, with specifics on what steps are necessary to extend the maximum useable life of these very expensive and delicate probes, as well as to insure the safety of both the patient and the user of the probe. Further, we will present examples of common TEE probe problems and how to identify them in a timely manner, while cost effective repairs can still be made. While it is clear that everyone involved with the maintenance of the echocardiographic devices in your department is responsible for providing the patient with a safe and efficacious echo study, the lead for ensuring this falls to the professional who handles the TEE probe on a daily basis. The clinical end-user, by virtue of their work, should normally be the first to observe any changes in the ultrasound image, spot any obvious structural damage to the TEE probe, observe any bite or drag marks in the insertion tube sleeve area of the probe, cracks in the case or tears in the cable, and any probe articulation problems with the insertion tube tip. Most importantly the clinical end-user and cleaning personnel should follow the Manufacturer's guidance regarding the use, cleaning, and pre-use testing of these probes. Any of the above signs of potential probe failure should be immediately reported to the hospital biomedical or clinical engineer as soon as they are discovered, and the use of the probe discontinued until the problem is resolved.

Replacing transducers is the highest cost component in the maintenance of ultrasound systems over the life-cycle of the system. The most expensive medical devices used with the echocardiography system, with the exception of the system itself, are the transesophageal transducers. The cost of a new TEE probe generally ranges from \$36,000 to \$50,000, depending on the type of TEE probe; with the higher amount being the newer 2D Matrix Arrays such as the Philips X7-2t or the GE 6Tv-D. When a TEE probe fails the cost of an exchange from the Original Equipment Manufacturer, or OEM, is generally in a range of \$21,000 to \$30,000. Even if the probe is under warranty or service contract, customer "abuse", or "avoidable transducer damage" determinations made by the OEM may result in the hospital paying for the exchange anyway.⁴ There are some very important, yet easy to implement and follow, preventive measures that not only extend the useful life of these expensive probes, but will also lead to improved patient safety, ensure clinical efficacy, and reduce the overall operating costs for the facility. The most important of these preventive actions are:

- Electrical leakage testing at the beginning of every disinfection cycle;
- Proper and consistent use of bite guards;
- Following the manufacturer's recommended disinfection procedures;
- Regular testing of the probe's articulation mechanisms;
- Regular visual inspection of the probe with special attention paid to the insertion tube sleeve;
- Careful handling, transportation and storage of the probe.

Electrical Leakage Testing

For TEE probes, almost all manufacturers' operator's manuals say that electrical leakage testing should be done before *every* patient exam. This instruction is given with good reason; a TEE probe that fails electrical leakage puts a potentially dangerous path to ground for current right behind the patient's heart. The more common patient safety risk is that of a hole or bite mark that breaches the coating or rubber insulation of the endoscopic shaft portion (insertion tube) of the probe. This type of insulation compromise not only causes the TEE probe to fail electrical leakage, but also causes an increased risk of cross-contamination and infection. Additionally, a TEE probe that fails electrical leakage generally has a puncture defect that allows fluid, such as the disinfectant that is used to clean the probe between patients, to migrate into (ingress) the insertion tube of the probe. These disinfectants have been known to leak out of the probe while it is inserted into the patient, and have resulted in reports of "burning of the patient's esophagus" and "illness following a (TEE) exam."⁵

The disinfecting solutions used with TEE probes are both electrically conductive and highly corrosive. Once these fluids are inside the TEE probe they can flow to other parts of the probe including the control housing and the transducer array inside the tip of the probe. Fluid infiltration sometimes cause an immediate failure of the probe, but even more serious damage will occur as a function of time as the disinfectant "eats away" at the vital components inside, such as the elements in the transducer array, any electronic components that may be in the tip of the probe (e.g., an ASIC, or thermistor), and the articulation wires (see photo below for example of the corrosive effect). The articulation wires within the endoscope shaft of the TEE probe connect the controls (usually knobs) located on the control housing to rings located between the bending neck rubber and the scanhead (tip), and are used to position the array in the scanhead so that the appropriate images can be obtained. If the articulation wires break or otherwise become sub-optimally responsive, which can happen due to wear, force, or more commonly, after a long period of exposure to disinfecting fluids, the probe will need to be repaired and the articulation wires replaced. If an articulation wire breaks while the TEE probe is inserted into the patient, it may cause patient injury when the probe has to be extracted from the esophagus without being able to properly straighten the end of the insertion tube.

Many of the failures outlined above associated with fluid ingress can be repaired, but if the corrosion damage is not caught early enough in the process the severity of the damage sometimes cannot be completely reversed and will eventually result in the necessity of replacing the TEE probe. Therefore it is essential that after every TEE procedure the probe insertion tube be closely inspected for any compromise to the integrity of the insulation. If a hole, suspected hole, or cut is seen in the insertion tube area, the probe should not be disinfected until electrical leakage and FirstCall⁶ or Aureon⁷ testing is performed by the Biomedical Engineer. The electrical leakage testing can be done with a device such as the iTest⁸ ultrasound leakage tester or the testing device provided with the TEE probe by the OEM. The FirstCall and Aureon devices are used by the Biomedical Engineer to determine any array, or element involvement. Electrical leakage testing should also be performed prior to or at the very beginning of the disinfection cycle, to avoid possible fluid infiltration into the TEE probe. A probe that fails electrical leakage must be taken out of use immediately, and not submerged into cleaning solvent.



Warning -- Be sure to read and follow the included instructions and the safety warnings specific to your particular ultrasound leakage analyzer provided by the OEM.

Use of Bite Guards

The “gag reflex”, or an involuntary bite response, can be a potential patient safety risk during any TEE exam. A bite guard protects the patient from potential injury and protects the TEE probe from damage. In Japan, for example, it is actually illegal to perform a TEE examination without using a bite guard. The OEM user manuals call for the use of a bite guard for every exam⁹, and if the probe is



damaged as a result of not using a bite guard the OEM will generally not cover the probe under warranty (see respective OEM operator's manuals for warnings in this regard). Not using a bite guard can also result in what is referred to as "tooth drag" or pulling the insertion tube over a tooth that may have a sharp edge, resulting in a cut or tear in the insertion tube. These cuts, holes or tears create a potential entry point for fluids. Proper use of the bite guard means placing and securing it in the patient's mouth *prior* to insertion of the TEE probe.

Proper Disinfection Procedures

The proper disinfectant is one that is listed as approved for use in the documentation provided by the OEM of the particular probe. This information is normally found in the TEE probe operator's manual and many of the OEMs also list approved disinfectants on their respective internet sites. The instructions on the disinfectant should be followed, and they include information such as how long the solution can be used once activated, how many minutes the transducer should be soaked, how to test the solution to ensure it is still effective and how to properly dispose of the solution. Using an unapproved disinfectant may result in voiding of the warranty on the probe, and may expose the probe to both premature failure and insertion tube discoloration or fading of the depth markers. Because of the importance of the disinfecting process close attention should be given to the methods used by the personnel disinfecting the transducer and the training they receive. This will ensure that the disinfection is done properly, consistently, and in a manner that is least likely to result in accidental damage to the transducer, or cross-contamination. Some essential points to consider for the disinfection process are:

- Electrical leakage testing should be done just prior to or at the very beginning of the soak cycle.
- Soaking the TEE probe for too long in a disinfectant will cause excessive wear and damage to the insertion tube.
- Proper ventilation is required to meet the OSHA Air Contaminants Standard (29 CFR 1910.1000).
- No disinfecting solution or rinsing water can be allowed beyond the end of the insertion tube, or liquids may potentially get into the probe or connector and cause failures.

- The transducer elements are located at the end of the insertion tube (tip) and are very fragile, so care needs to be taken to not have the tip impact any hard surface such as a table or a sink basin.

The use of a specially designed, FDA 510(k) cleared, automated TEE disinfecting device such as the CS Medical model TD-100¹⁰ (shown below) is highly recommended for safely, consistently, and effectively disinfecting TEE probes. This automated device mitigates many handling and cleaning issues that are primary causes for TEE probe after-use failures associated with handling and over-soaking.



CS Medical TD-100

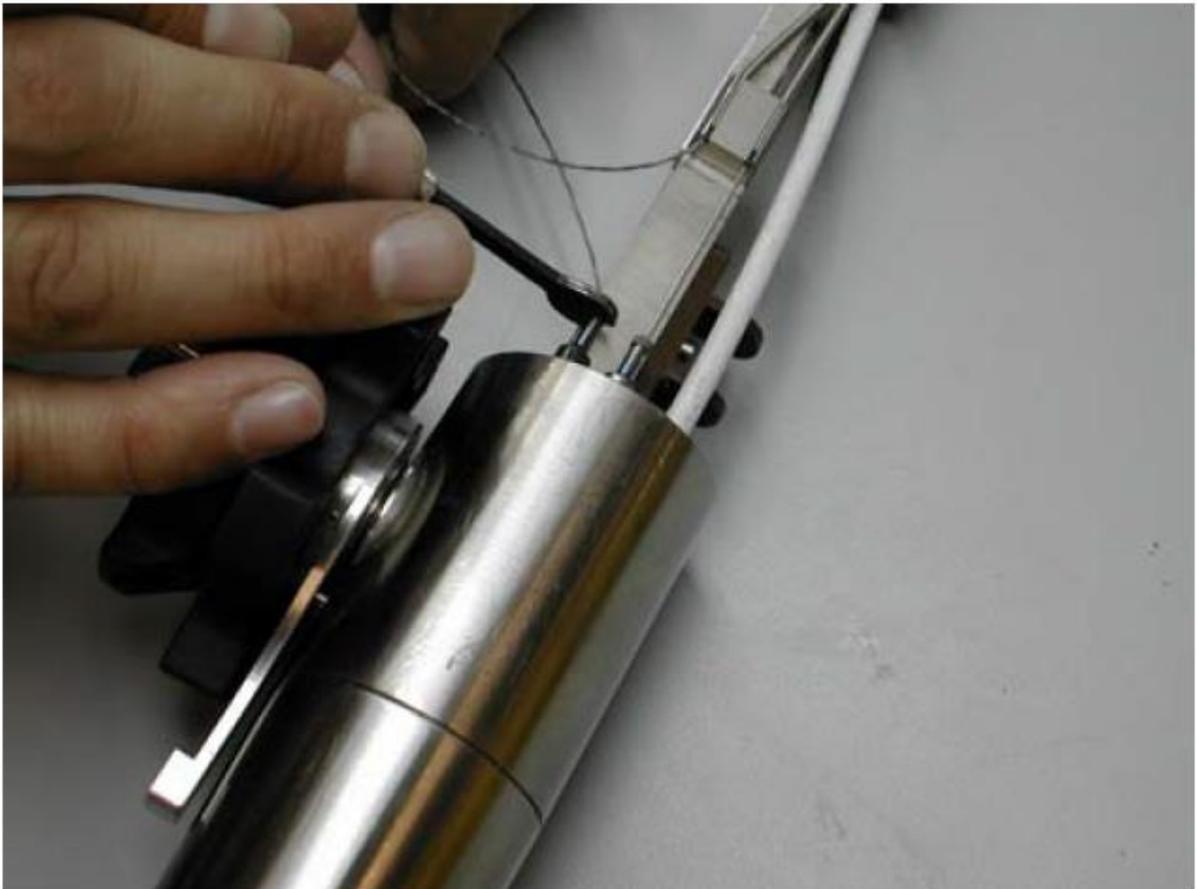
Testing the Articulation Mechanism

The articulation mechanism is comprised of control knobs on the control housing of the TEE probe, which connect to very thin cables that are routed through the insertion tube to the scanhead (tip). The articulation knobs are used to move the tip of the TEE probe (along with the transducer array) into various positions and angles needed in order to obtain and maximize the desired scan image or Doppler. Over time and with frequency of use, this articulation mechanism will wear (e.g., loosen, or become "sloppy" and unresponsive), be damaged by fluid infiltration and the resultant corrosion, or be damaged by improper handling and use of the TEE probe. As stated earlier in this paper, a failure of the articulation mechanism while the probe is inserted into the patient's esophagus presents a potential safety hazard. For this reason, daily testing of the articulation mechanism is important to detect any changes in the mechanical performance of the mechanism so that repairs can be made early in the failure process. Personnel that use or clean TEE probes regularly should be trained to do this articulation testing and know what to look for in terms of changes in performance or function. In-house biomedical engineering personnel, OEM personnel, or an independent ultrasound field service engineer should also check the articulation performance during regularly scheduled preventive maintenance service calls. Depending upon frequency of use, it is recommended that this mechanical inspection be done once per day and any changes noted in an equipment log.

To check the articulation:

1. Hold the TEE probe with the insertion tube in a position so that the scanhead end (tip) can move freely. The scanhead and bending neck sheath should be in line with the rest of the insertion tube.
2. Move the first articulation knob slowly in one direction. The scanhead should start to deflect (move) as soon as the knob is turned, and should move smoothly throughout the full deflection as the knob is turned. Then the knob should be turned so that the scanhead and bending neck are in line with the insertion tube again.
3. Hold the TEE probe with the insertion tube in a position so that the scanhead end (tip) can move freely. The scanhead and bending neck sheath should be in line with the rest of the insertion tube.
4. Move the first articulation knob slowly in one direction. The scanhead should start to deflect (move) as soon as the knob is turned, and should move smoothly throughout the full deflection as the knob is turned. Then the knob should be turned so that the scanhead and bending neck are in line with the insertion tube again.
5. Move the first articulation knob slowly in the other direction; again checking to make sure the deflection of the scanhead is immediate and smooth.
6. Repeat the tests using the other articulation knob.
7. Any variances noted should be reported to the Biomedical Engineering for confirmation and the probe should be sent in for repair and articulation re-calibration.
8. Hold the TEE probe with the insertion tube in a position so that the scanhead end (tip) can move freely. The scanhead and bending neck sheath should be in line with the rest of the insertion tube.
9. Move the first articulation knob slowly in one direction. The scanhead should start to deflect (move) as soon as the knob is turned, and should move smoothly throughout the full deflection as the knob is turned. Then the knob should be turned so that the scanhead and bending neck are in line with the insertion tube again.
10. Move the first articulation knob slowly in the other direction; again checking to make sure the deflection of the scanhead is immediate and smooth.
11. Repeat the tests using the other articulation knob.
12. Any variances noted should be reported to the Biomedical Engineering for confirmation and the probe should be sent in for repair and articulation re-calibration.
13. Hold the TEE probe with the insertion tube in a position so that the scanhead end (tip) can move freely. The scanhead and bending neck sheath should be in line with the rest of the insertion tube.

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16. Move the first articulation knob slowly in the other direction; again checking to make sure the deflection of the scanhead is immediate and smooth.
17. Repeat the tests using the other articulation knob.
18. Any variances noted should be reported to the Biomedical Engineering for confirmation and the probe should be sent in for repair and articulation re-calibration.



Control Housing Articulation Wires

Visual Inspection of the TEE Probe

A TEE probe should be visually inspected at least once per day, and many OEM user manuals call for this to be done prior to each patient examination. Acertara recommends using an off-the-shelf magnifying glass or 10x loupe when scanning the length of the insertion tube up to the tip. Black insertion tubes often make it difficult to spot small holes or tears in the insulation material. This inspection is best done under a bright light so that any irregularities may be more easily identified. A few examples of problems to look for are shown in the following photos. The suggested checklist of things to look for is:

- Cuts, air bubbles or gouges on the lens material;
- Condition of the bend reliefs (connector and each side of the control housing);
- Cracks or other signs of damage to the connector;
- Cracks or other signs of damage to the control housing;
- Bent or damaged pins in the probe connector
(If using a “pin-less” connector, e.g., Siemens/Acuson Sequoia probes, inspect the surface of the connector to insure it is clean);
- Integrity and flexibility of the insertion tube;
- Bite marks on the insertion tube sleeve or the acoustic lens.



**Scratching on the
Acoustic Lens**



**Tooth Drag Marks on
Insertion Tube Sleeve**

NOTE BENE:

Defects like those shown above may be sources of biological loading if not cleaned properly; extra care should be given in cleaning any TEE probe that has excessive wear, or indentations.

TEE Re-coating and Re-Labeling



Before Re-label

After Re-label

One of the more common needs for repair on TEE probes is to re-coat and re-label the depth markers (shown above). These marks fade as a function of use and through the disinfecting process, especially if the disinfecting process is a manual one where over-soaking can be a potential problem. After the Acertara re-coating and re-labeling process, the depth markers and the outer protective coating of the TEE insertion tube are fully restored to their original new condition. It should be noted that OEMs generally do not cover discoloration or fading under warranty.¹¹

A Suggested TEE Probe Inspection Routine

Inspect Carefully for the Following (use of a magnifying glass or 10x loupe is recommended)

- Cracks on the control housing, non-responsive insertion tube articulation
- Cracks and scratches on the TEE tip
- Cuts or gouges on the lens material
- Obvious signs of the fluid ingress
- Condition of the bend relief(s)
- Cracks or other signs of damage to the connector
- Bent or damaged pins in the probe connector
- If using a probe with a “pin-less” connector (e.g., GE, Vivid E9) inspect the surface of the connector to insure it is clean
- Integrity and flexibility of the insertion tube, including fading or absence of the depth markets
- Bite or drag marks on the insertion tube sleeve rubber

What Can Hurt a TEE Probe

- Electro-static discharge on or around the lens of the probe, or the pins on the probe connector
- Not using bite guards on a consistent basis
- Rapid deceleration trauma (dropping the probe), or other blunt force trauma, especially during a manual cleaning process where the probe is handled
- Using the wrong disinfecting agents, or using the correct ones in the wrong manner
- Improper storage, handling and transportation
- Not freezing the image before removing or connecting a probe to the system
- Improper or insufficient cleaning

What Preventive Measures Can I take?

- Inspect the probe on a daily basis – use a magnifying glass or loupe to inspect the lens and insertion tube, pay special attention to the insertion tube sleeve area. Inspect under sufficient light
- Follow the recommendations for use and cleaning in the probe operator's manual
- Have the probe regularly tested on a daily basis, or if a problem is suspected. This is for both electrical and mechanical articulation evaluation
- Use the system probe holders when probe is not in use

What Else Should I Be Doing?

- Electrical leakage testing as recommended by the Original Equipment Manufacturer
- Involve your hospital Biomedical Engineer in regularly testing the probe elements
- Establish with your Biomedical Engineering Department a comprehensive ultrasound QA program that includes not only the probes, but the ultrasound system as well
- If you suspect a probe is compromised in some manner, **don't use it until it is tested**

Careful Handling of TEE Probes

It cannot be over-emphasized that all the personnel using and disinfecting TEE probes need to be properly trained on how to test, inspect, transport, and handle these probes. This includes the physicians, echocardiographers, the personnel in the OR, and the people that disinfect the probes. Dropping or banging the TEE probe can cause serious damage. Even a slight impact can seriously damage the acoustic array, which is made of piezoelectric crystals; as fragile as glass. The people that disinfect the TEE probes may not even realize what part of the probe is the most vulnerable to damage without proper training. Physicians also need to be informed and reminded from time-to-time about the proper and consistent use of bite guards and the safe handling of the probes.

Checklists should be used by the different people using and handling the TEE probes, to ensure that they are testing and inspecting them regularly and to document the electrical leakage tests, any mechanical issues or changes with probe articulation, and the proper use of bite guards. These checklists will aid in determining causes of damage, detect failures earlier in the process when they can still be safely and effectively repaired, and provide objective evidence for inspectors and auditors of regulatory or accrediting agencies that an effective QA process is in place. Audits of the people handling the TEE probes on an ongoing and regular basis will help ensure that procedures are being followed and also help identify areas for improvement. The high risk and expense associated with these probes makes these efforts worthwhile, and cost effective.

Acertara has published a white paper called *Common Ultrasound Probe Failures* that is an excellent tool to use in training people on inspection of ultrasound probes.



TEE Electrical Leakage Device - AmpSafe

Conclusion

The TEE transducer is the most sensitive and most often damaged link in the ultrasound image quality chain. Because the echocardiographer or physician handles the transducer during the ultrasound examination, it is susceptible to all manner of physical damage resulting from accidental dropping, aggressive cleaning methods, or other traumatic occurrences such as banging. In our experience, high-use TEE transducers used in a facility without an effective QA program generally display some form of performance compromising anomaly within 6 to 14 months after being placed into service. During the ten-year (120 months) operational life span of a premium quality ultrasound system, a TEE transducer could potentially be replaced up to five times, simply due to “normal” use. Without an adequate TEE QA process in place probes could be replaced as often as every 6 to 9 months. At an average cost of ~ \$21,000 per TEE transducer replacement, the financial impact of replacing transducers to the hospital or clinic becomes quite apparent.

An active and comprehensive ultrasound EBQA (evidence-based quality assurance) program can substantially lower costs for hospitals by identifying TEE probes early enough in the failure process that they can be repaired rather than replaced. For example, new transesophageal (TEE) probes can cost \$50,000 or more and a replacement (meaning the damaged one is exchanged for another one) TEE probe normally costs as much as \$30,000 from the OEM. If the TEE probe is damaged and the damage discovered in time so that it is repairable, the repair cost is normally 25% or less than the cost of replacement. Over the ten-year lifespan of the ultrasound system in this scenario, it could mean the difference between as much as \$300,000 in replacement costs versus less than \$75,000 in repair costs, or less because an effective EBQA program will also drive down the number of failure occurrences. Even more important than the expense cited above, is that a properly maintained TEE probe is both safe and clinically efficacious.

References

- 1) "The Methods and Effects of Transducer Degradation on Image Quality and the Clinical Efficacy of Diagnostic Sonography". In the Journal of Diagnostic Medical Sonography, January/February 2003, VOL. 19, NO.1, Weigang, Moore, et al
- 2) "The Silent Revolution: Catching Up with the Contemporary Composite Transducer". In the Journal of Diagnostic Medical Sonography, November/December 2004, VOL.20, NO.6, Powis, PhD, FAIUM, Moore, MA, FASE, et al
- 3) "The Need for Evidence-Based Quality Assurance in the Modern Ultrasound Clinical Laboratory." In the Journal of the British Medical Ultrasound Society. 2005, Moore, Schafer, PhD, et al
- 4) EnVisor Series Reference Manual, Philips Medical, 3000 Minuteman Rd., Andover, MA, Page 21, Transducer Setup
- 5) "Chemical Burn Injury Secondary to Intraoperative Transesophageal Echocardiography" In the Journal of Cardiovascular Anesthesia, Anesth Analg 2003;97:1260-1261, Venticinqu, Steven, MD, Kashyap, Vikram, MD, et al
- 6) FirstCall Probe Testing Device
- 7) Aureon Probe Testing Device, Acertara Acoustic Laboratories, 1860 Lefthand Circle, Suite H, Longmont, CO 80501. 303 834.8413. www.acertaralabs.com
- 8) AmpSafe Electrical Leakage Tester – Acertara Acoustic Laboratories, Longmont, Colorado
- 9) GE Medical Technical Publication Part Number KZ191683 Revision 4, TEE Probe Troubleshooting/Inspection Manual, Page A-2
- 10) TD-100 TEE Probe Disinfectant, CS Medical, 3300 Lake Woodard Drive, Raleigh, NC 27604
- 11) GE Medical Technical Publication Part Number KZ191683 Revision 4, TEE Probe Troubleshooting/Inspection Manual Page B-1



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