Equipment Acceptance Testing: Demystifying the Process

The equipment acceptance testing of a new gamma camera can be an arduous, complicated process. Matching a new camera's performance with the standard measurements and specifications as set forth by the National Electrical Manufacturers Association (NEMA) can often seem as elusive as finding the Holy Grail. A relatively routine installation takes two to three days at minimum to complete. However, complications in the testing can escalate quickly, including measurements that never seem to come close to the NEMA requirements and certain parameters that can't even be measured because the special equipment needed is unavailable. Worse still, nuclear medicine departments in smaller hospitals may not even have a medical nuclear physicist on staff who can perform the tests and must rely on paid consultants who, because of the overwhelming demand for their services, may or may not be available during the period the imaging equipment is installed. (See "To Hire or Not To Hire a Consultant," accompanying.)

Given all the problems inherent in the process, one might wonder: why bother doing acceptance testing at all?

"When you submit a request for a proposal to buy a new gamma camera today, you're talking about spending hundreds thousands of dollars. The acceptance test is the mechanism that verifies you're getting exactly what you paid for," said Paul Murphy, PhD, professor in the Department of Radiology at Baylor College of Medicine in Houston, Texas, and head of medical physics and radiation safety at St. Luke's Episcopal Hospital, the Texas Heart Institute and Texas Children's Hospital.

Another reason why the measurements made during an acceptance test are extremely important is because they set the standard thereafter for the continuing quality control of the system. Testing also allows for checking those aspects relating to the safe operation of the system, especially patient safety issues.

"The community recognizes the NEMA protocols and everybody follows them in the United States," Murphy pointed out. "It's best to match those measurements as closely as possible. But in the real world they can't always be accurately reproduced."

Indeed, attempting to replicate the NEMA measurements can often be a big headache, even for an experienced medical nuclear physicist. Many of the tests require special equipment such as special phantoms that hospitals may or may not have available. NEMA publishes a manual (NEMA Standards Publication NU 1-1994, "Performance Measurements of Scintillation Cameras") which lists the protocols for testing but does not provide alternative testing methods. If any test cannot be performed according to NEMA's protocols, then an alternative method for testing that particular parameter will have to be devised on the spot.

"That's where the expertise of a medical nuclear physicist is necessary," said Murphy. "A medical physicist can be innovative in designing and substituting a test for a particular parameter and still be able to interpret the results."

Manufacturers do conduct their own equipment testing at the factory prior to delivery. The computer database on most camera systems should contain a file copy of those measurements. However, Murphy stresses that the manufacturer's measurements should only be accessed for informational purposes. "I think it was President Reagan who said, 'trust but verify.' There's no question that an acceptance test on a new system should be required, and it should be done independent of the results supplied by the manufacturer."

The NEMA manual lists detailed measurements and reporting techniques for the specification of 17 different parameters. All of these parameters are equally important and should be tested. The following are five common parameters that would be routinely measured during the course of an acceptance test on a single detector system, as well as some of the modifications that a medical nuclear physicist might make to the NEMA protocols.

Intrinsic Spatial Resolution. This measurement is done with the collimator removed. A special phantom, a lead mask, is required in order to measure line spread functions. If the phantom is unavailable during installation, the resolution can be measured extrinsically. "That can be done fairly easily by filling capillary tubes with Tc-99m and running count profiles across them," Murphy said. "It's not as sensitive as measuring them intrinsically, but extrinsic resolution is also specified as part of the camera performance parameters, so it's the next best thing."

Another alternative method for measuring intrinsic resolution can be done subjectively by studying bar phantom images and identifying minimum bar spacing which can be resolved visually. "It's a rough rule of thumb that spacing times 1.75 will be a reasonable estimate of the Full Width at Half Maximum (FWHM) of the line spread function which is a parameter that NEMA specifies."

Intrinsic Energy Resolution. This measurement is done by collecting a pulse height spectrum for Tc-99m and for Co-57. "Knowing exactly the differences in energy between the two peaks of those two spectra, one can calibrate the energy scale," Murphy noted. "By looking at the distances between those two peaks and using that measurement, one can calculate the FWHM of the photopeak for Tc-99m and express it as a percentage of its energy."

Sensitivity. The measurement for sensitivity consists of estimating the count rate per unit activity coming through the collimator, which should be done for each collimator. "For this measurement, one should take a petri dish about 4 in in diameter, put in a small volume of a radioactive material of known activity, and then count it for a fixed period of time. The results can be expressed as counts per minute, per microcurie or per millicurie," Murphy said. "The numbers can then be checked against the NEMA specifications. "

Uniformity. This parameter measures the response of the detector to a uniform flux of gamma rays. The measurement is made by exposing an uncollimated detector to a uniform distribution of gamma rays by using a point source, such as a small volume of Tc-99m in the tip of a syringe. However, it requires being able to back away from the detector at least five times the maximum dimension of the detector, far enough that the distribution of the gamma rays is within 1% uniformity based upon the divergence of the gamma rays coming from the point source.

"For a multidetector camera, it's sometimes difficult to get a point source back far enough without one of the other detectors shielding the source," said Murphy. "So it's more practical to measure uniformity extrinsically, through the collimator with a sheet source, a distributed source of either Tc-99m or Co-57."

Spatial Linearity. "Without a special phantom, the same type used for spatial resolution, this measurement is very difficult to measure quantitatively. It's a multiple-slit phantom used to observe the location of the straight lines of gamma rays on the detector and calculate their deviation from a straight line," Murphy pointed out.

An alternative method would be to use a regular array phantom, such as an orthogonal hole phantom, a line phantom or a quadrant bar phantom, and subjectively evaluate any nonlinearities. "Just make sure it's measured in both the x and y directions so that it essentially is being measured over the face of the entire crystal," Murphy advised.

Common measurements for SPECT camera systems also include reconstructed spatial resolution, checking the center of rotation, uniformity correction, multidetector matching and collimator integrity.

"One thing that shouldn't be overlooked in an acceptance test is safety," said Murphy. "For example, we recently installed a camera and got it moving around in SPECT-mode. We hit the emergency stop buttons to make sure it would stop, but one of the buttons wouldn't reset so that the camera could be restarted again. Had we left it unchecked, we wouldn't have discovered the problem until it materialized during the middle of a patient scan. That would have meant a service call from the manufacturer, not to mention a great inconvenience to the patient."

— Jeff Williams

To Hire or Not To Hire a Consultant

Many hospitals, particularly smaller ones, have no nuclear medical physicist on staff. For those hospitals, the best alternative is to hire a consultant physicist for the job.

"An acceptance test on a complicated SPECT system can take a couple of days. It is very helpful to have someone present who can work with the service engineers installing the system," said Paul Murphy, PhD, Department of Radiology, Baylor College of Medicine and St. Luke's Episcopal Hospital. "Being on site during the installation, an outside consultant physicist would have access to the special test devices and phantoms brought by the installation team. A consultant can also act as an intermediary between the company and staff physicians, especially if there are technical problems."

Hiring a medical nuclear physicist on a consultant basis can be expensive. Depending upon the type of system being installed, fees can range from $2,000 to $6,000, plus travel expenses. Consultant costs for a single detector system would be on the lower end of the scale while multidetector systems with coincidence capabilities could bring higher fees. To avoid any possible budgetary problems and/or delays, Murphy suggests that the fees for the testing be included as part of the purchase agreement.

For those who might consider foregoing the acceptance test in order to save costs, Murphy adamantly warns against it. "It could end up being an expensive mistake to rely upon the vendor's word that the equipment is performing up to specifications," he said. "Installation is often done by local service engineers who don't necessarily have the same fundamental knowledge of the underlying operating principles and parameters of a complicated gamma camera system as a medical nuclear physicist.