Instrumentation

Troubleshooting Nuclear Medicine Instrumentation Problems

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Because the ultimate goal of any nuclear medicine procedure is to obtain diagnostically reliable images in the most cost-effective manner, troubleshooting of instrumentation problems is an integral part of this specialty. Many instrumentation problems can be rectified without serviceman intervention by the technologist who has proper knowledge of the equipment involved. An outline of common equipment problems and a systematic scheme for diagnosis and rectification of these problems are presented.

Quality control procedures assure top performance of nuclear medicine instrumentation and aid in the diagnosis of malfunction. For these reasons, the performance of every nuclear medicine system is assessed daily to ensure diagnostically reliable images. Once proper equipment function has been verified, patient studies are initiated. Conversely, if a quality control procedure exposes a malfunction, the appropriate servicing steps are initiated. Many instrumentation problems can be rectified simply by a technologist knowledgeable about the equipment involved, without violating any of the agreements stipulated in service contracts.

Technologist intervention and correction of equipment problems (troubleshooting) can eliminate diagnostically unreliable images and reduce unnecessary system down-time and monetary expenditures if system repair is not covered by service contracts. Nuclear medicine detecting systems are affected by a variety of intrinsic and extrinsic factors, including environment, dust, and electronic fluctuations. While many of the equipment malfunctions manifest themselves on daily quality control procedures, component problems can occur anytime during the day. It is important for the technologist to be aware at all times that a potential problem could occur and to be able to verify and correct a problem whenever possible. While pathologic processes may sometimes mimic equipment problems, it is important that the equipment malfunction does not mimic a patient disease state that does not exist. A diagnostically reliable image is directly related to the technologist's ability to troubleshoot existing and potential equipment problems. We have devised a systematic list of common problems for various nuclear medicine instrumentation systems and have also outlined procedures to rectify some specific problems.

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I. Scintillation camera systems (*1-4*)

A. Problem: Nonuniformities noted on field flood or patient study images (Table 1A)

1. Causes and solution—

a) Incorrect photopeak adjustment

An incorrect photopeak setting will present nonuniformities characteristic of the scintillation camera involved. On some camera systems, nonuniformities can be striking because photomultiplier tube differences are enhanced at off-peak settings. With the advent of uniformity field correction devices, correct peak adjustments for the daily flood is especially important; this flood pattern is stored in memory and used to correct subtle voltage drifts throughout the course of the day. If a multichannel analyzer is available on the camera system, peak the camera with this device since it is most accurate (*5*). Double check the peak setting with the spectrum or ratemeter controls to counter-check proper peak adjustment (Fig. 1).

b) Incorrect collimation

Check the collimation on the detctor. Diverging, converging, or medium-energy collimators can sometimes cause bizarre patterns. The "waffle" pattern, for example, is most obvious on a field flood obtained with the medium energy collimator when imaging low energy gamma emissions.

c) Improper flood source for quality control procedures

Commercially available Co-57 flood sources assure a uniformly mixed gel within the solid housing. However, with prepared liquid Tc-99m sources, care must be taken to make sure the source is well mixed to provide

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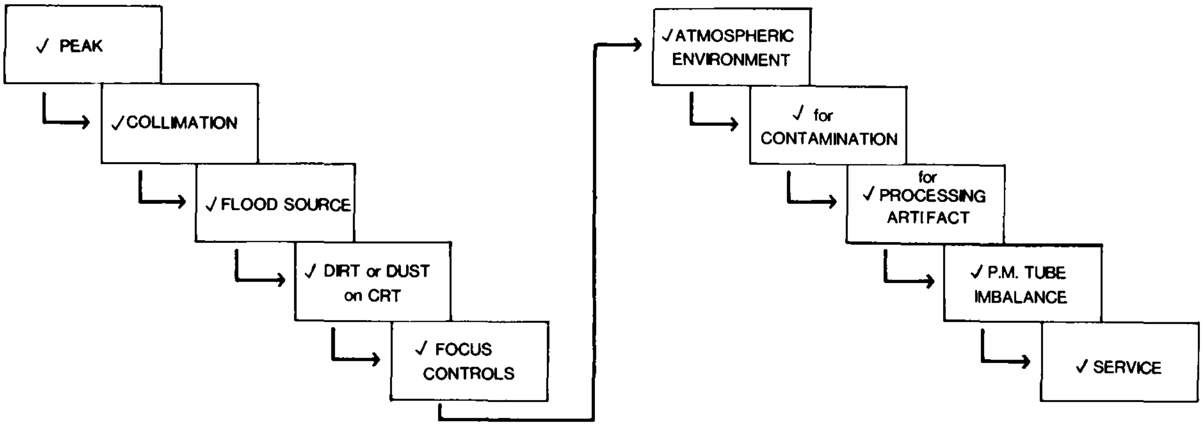
TABLE 1A. Scintillation Camera Systems Check List

Nonuniformities noted on field flood or patient study images



a uniform distribution of radioactivity. Bubbles within the source or an unevenly distributed mixture can result in a nonuniform field flood image. Also, when source activity is too intense, whether it be with the commercially available Co-57 or daily prepared Tc-99m sources, nonuniformities and apparent loss of resolution will result (Fig. 1).

d) Foreign bodies or dust on the CRT face or on the multi-imager lens

Change the camera orientation 90° and acquire another image. If the defect does not move with the change in orientation, the problem is probably due to dirt or dust on or behind the CRT screen if you're using a Polaroid camera; if you're using transparencies, check the multi-imager mirrors or CRT. Inspect these components visually, clean them with lens paper, and repeat the image acquisition.

e) Misfocused dots or incorrect bellows adjustment

Incorrect focus controls can create image nonuniformities. Visually inspect the image for sharp dot focus. Misfocused dots will appear large and ovoid rather than discretely pin-point in shape. Multi-imager dot focus can be easily adjusted but check to see if entry into the unit is permitted in your service agreement. Some Polaroid camera systems are bellows-type cameras. The distance from the CRT face to the camera lens can be controlled by moving the bellows in or out. Bellows-type cameras are common on portable camera equipment. Due to the constant rearrangement and jarring of the equipment, the bellows-to-CRT distance may be inadvertently moved to an incorrect placement. Check the distance for your system and repeat the image acquisition.

f) Improper atmospheric environment

Scintillation camera systems operate best in a temperature/humidity environment that people find most comfortable. Ambient room temperatures between 68–72°F with a noncondensating humidity of 40 to 45% provide the optimal operating environment. The more sophisticated the circuitry, the more crucial the operating environment becomes. Scintillation camera detectors can generate an inordinate amount of heat despite the fans designed to cool the camera's internal components. Some equipment manufacturers will not install instruments unless a constant, favorable operating environment can be guaranteed. An operating environment too hot or too humid may result in image distortions that drastically change within short time intervals, sporadic equipment malfunctions, and, in the worst possible

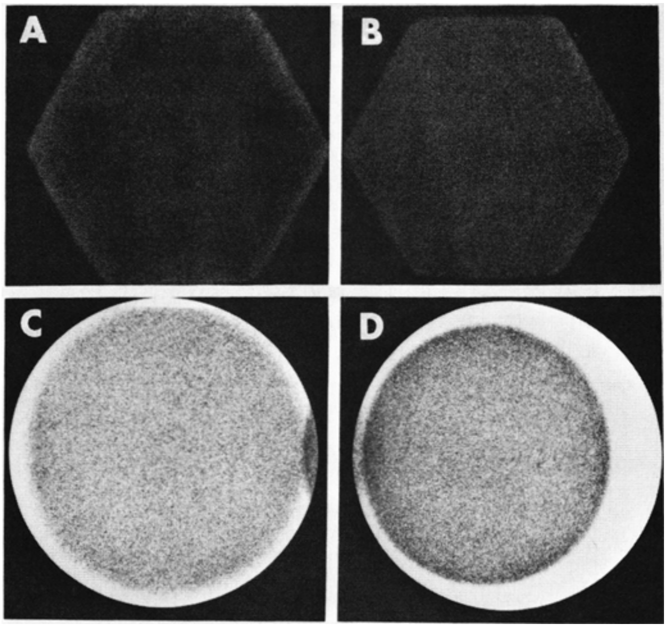


FIG. 1. Effect of mis-peaking and incorrect flood source on field flood uniformity. (A) Gross, striking nonuniformity is seen when a Co-57 flood is erroneously peaked on Tl-201 settings. (B) Correctly peaked field flood. (C) Flood performed with high activity demonstrates spatial distortion and blurred contours. (D) Flood obtained with appropriate source.

situation, a damaged crystal. Drastic environmental changes are not needed to damage a crystal; subtle temperature/humidity changes are all that is necessary.

Figure 2 shows a Tl-201 scan performed in our department with some unusual hot spots noted. These anomalies were not seen on Tc-99m scans nor on the Co-57 quality control field flood image. Only when field floods or studies were performed with Tl-201 were they present. The serviceman confirmed moisture deposition within that portion of the crystal closest to the aluminum housing, the part where lower energy gamma interactions occur. Installation of a new crystal corrected the problem (*6*). Field flood examinations with Au-195, a simulated Tl-201 source, is a useful adjunct to the routine Co-57 field flood in our laboratory to detect possible early recurrence of a problem of this nature. If an operating environment becomes too hot or humid, every effort should be made to remove the equipment from the area or change the abnormal condition within the area by means of portable fans until it can be permanently stabilized. Once the environment has been properly stabilized, daily work can be resumed after repeating quality control measurements.

g) Detector collimator left side up for a prolonged time

A detector collimator left side up overnight or over a weekend may cause nonuniformities, depending on the individual camera system involved. Migratory heat from the pre-amplifier boards can result in some nonuniformity presentations. Turn the detector collimator side down, wait about 30 min, and repeat the field flood.

h) Contamination

Contamination present anywhere within the imaging system's field of view will result in distorted images. Direction of the detector should be changed to rule out the

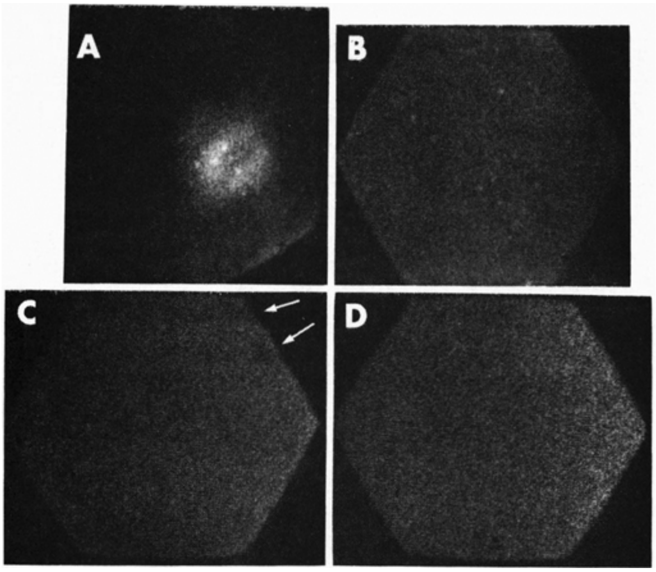


FIG. 2. (A) Thallium-201 study performed on a camera with crystal hydration. (B) Associated Tl-201 field flood. (C) Field flood performed at room temperature of 80±3°. (D) Field flood performed at room temperature of 70±2°.

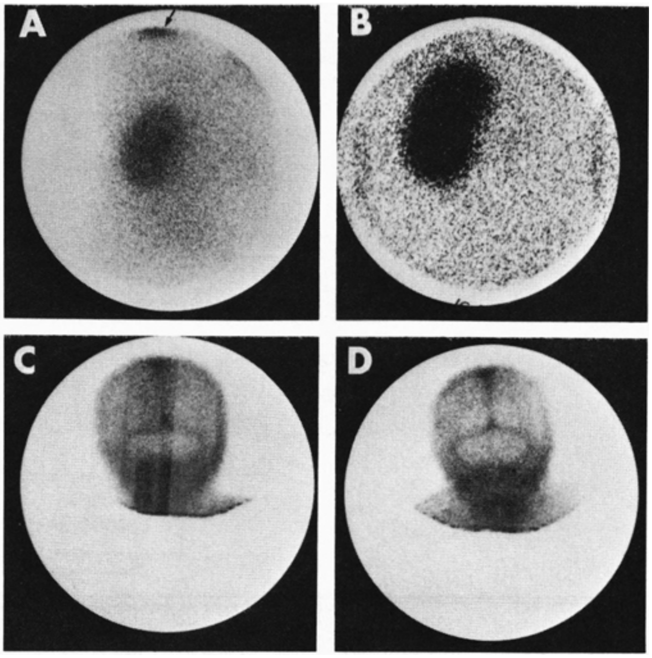


FIG. 3. (A) Surface contamination on inside of collimator noted on renogram study. There is image degradation caused by uncollimated scatter from the contaminating source (arrow). (B) Same study on a different camera/collimator system. (C) Processor roller artifacts noted on brain image. (D) Repeat image after processor rollers were cleaned.

possibility of contamination within the external imaging area. Removing the collimator and performing an uncollimated field flood will determine whether the source of contamination is on the collimator or on the crystal housing. Cleaning the crystal housing or collimator and locating and removing the external source will correct the image distortion on repeat images (Fig. 3 A and B).

i) Processing artifacts

Developer streaks caused by unevenly distributed film emulsion and film processor streaks can simulate nonuniformities on both Polaroid and transparency images. These problems can usually be detected by visual inspection of the image. Clean the camera or processor rollers to rectify the problem (Fig. 3 C and D).

j) Photomultiplier tube imbalance

If a photomultiplier tube imbalance is present, a repeat field flood collected at a 90° change in orientation will cause the image defect to move in an analogous 90° pattern. If a problem exists within the CRT display, the defect will not move, as stated above in (d). For additional information, store the image in a computer system. A photomultiplier tube imbalance will be visible on the computer image as well. A CRT or multi-imager problem will give a discrepant camera-computer image. Many scintillation camera systems are equipped with photomultiplier tube balance potentiometers at easy access. Follow the appropriate camera manual procedure book for the proper photomultiplier tube balancing technique.

k) Intrinsic camera malfunction

The appropriate service personnel must be notified if all of the above measures are tried but the problem persists.

B. Problem: Shifts in intensity settings (Table 1B)

1. Causes and solutions

a) Incorrect f-stop setting on Polaroid camera

Over or underexposed photographs are usually the result of the f-stop setting being inadvertently in an incorrect position. This occurs most frequently in equipment used in a portable mode. Check the f-stop position and move it to the appropriate setting (Fig. 4).

b) Incorrect photometer calibration on the multi-imager system

For transparency images on multi-imager units, a light calibration device needs to be adjusted each time a new intensity factor is dialed in. Failure to do so will result in improperly exposed transparency studies. Some multi-imager systems also have a flip-switch that introduces a filter across the multi-imager lens face to permit light filtering for proper image exposure. These filters will sometimes only partially move in or out of place or not retract at all, creating image exposure problems. If permitted in your service contract, enter the multi-imager unit and check for proper switch function. Oftentimes this malfunction can be easily corrected by a simple adjustment (Fig. 4).

c) Intrinsic CRT or multi-imager malfunctions

Notify the appropriate service personnel and inform them of the parameters you have already investigated; this will save personnel time in locating the problem area when they arrive.

C. Loss of system power (Table 1C)

1. Causes and solutions

a) Emergency stop knob depressed

As a safeguard for patient and technologist protection, some scintillation cameras are equipped with emergency stop controls which, when depressed, will shut down power and prohibit detector movement. A disengagement of the knob will restore detector power.

b) Circuit breaker engaged

Locate the system circuit breaker, if it has one, and flip the switch back to the "on" position. The reason why the circuit breaker disengaged should then be investigated since an electrical short circuit somewhere within the system, usually within the hand control or detector movement controls, is a potential recurrent problem. Once the problem source is isolated, appropriate servicing steps can be initiated.

c) Fuse problems

Locate all fuses in or behind the detector assembly or in the console and make sure you have spare fuses of the proper amperage available. Fuses are usually at easy access points and are a common source of location of the problem. Continually blown fuses should be more stringently investigated since this is indicative of a more complicated electrical problem.

d) Loss of alternating current from main power line

Check the main power plug board for AC current. Verification of a problem at this site would necessitate notification of local or hospital maintenance personnel.

e) Intrinsic malfunction

Notify the appropriate service personnel.

TABLE 1B. Shifts in Intensity Setting

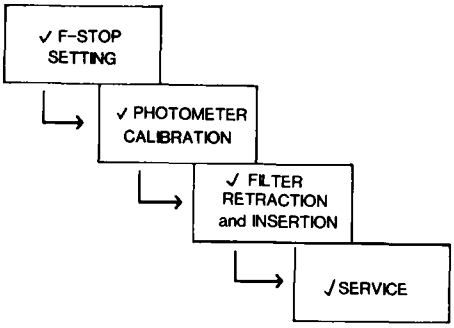
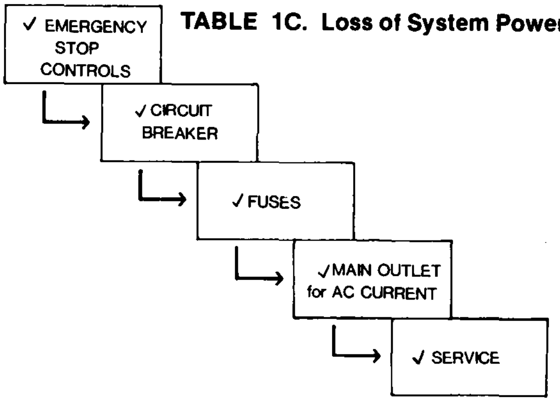


TABLE 1C. Loss of System Power



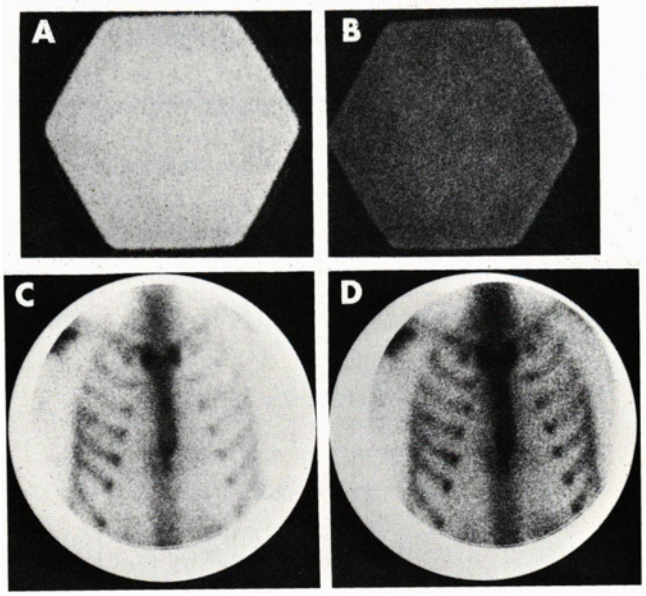


FIG. 4. (A) A field flood at f-stop of 8 for 500,000 counts results in overexposed image. (B) A field flood at an f-stop of 11 for 500,000 counts results in a properly exposed image. (C) Improper retraction of the multi-imager lens filter causing left chest to appear lighter. (D) Repeat images after filter is completely retracted.

II. ECG gating devices (Table 2)

The R-trigger from an electrocardiograph tracing is necessary for gated cardiac studies. A constant, reliable ECG tracing is mandatory for diagnostic accuracy in gated study interpretation. Since the patient's actual heart rate cannot be controlled, those external factors that affect the ECG tracing reliability can and should be controlled.

A. Problem: Discontinuous ECG tracing

1. Causes and solutions

a) Poor electrode-to-skin seal

Self-adhering electrodes can become loose during a gated study due to perspiration or oily skin surface, particularly in exercise studies. Loosened electrodes can produce artifactual spikes on the ECG tracing, which can be misinterpreted as an R-trigger by the computer. Continuation of the study under these circumstances will result in erroneous ejection fraction determination. Prior to attaching the electrodes to the patient, clean the area thoroughly with alcohol and wipe completely dry. Apply the electrodes firmly to the cleaned areas and check them at periodic intervals during the course of the study to ensure proper electrode-skin contact (Fig. 5).

b) Incorrect electrode placement

Electrodes must be placed in such a manner as to obtain the best QRS complex on the ECG tracing. Moving an electrode closer to the heart can improve the amplitude of the QRS complex resulting in better separation between the R- and T-waves. Changing the gain control on the instrument will amplify the QRS complex for a better tracing. Changing electrode polarity is oftentimes necessary to invert high spikes due to interference caused by premature ventricular contractions. Changing polarity to a negative mode inverts the premature ventricular contraction spike and it is no longer interpreted by the computer as an R-trigger (Fig. 5). Artifacts on ECG tracings due to respiratory movement are also enhanced during exercise studies. This problem can be minimized by moving the left lateral electrode away from the diaphragm and more towards the midline of the body.

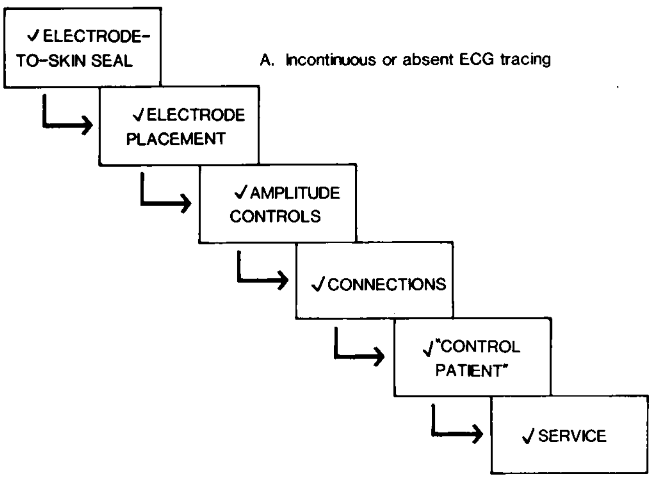
c) Loose connections

Poor fitting cables and loose connections will create sporadic discontinuous tracings. Check all cables and connections for tight unions.

d) Intrinsic malfunctions within the gating device

Attach the electrodes to a "control" subject or to yourself. If you still get an erratic tracing, you can be reasonably sure the gating device is faulty. The appropriate servicing steps should be initiated.

TABLE 2. ECG Gating Devices Check List



III. Scintillation counters (Table 3)

A. Problem: calculated test values in discrepancy with the patient's other clinical data

1. Causes and solutions

a) Incorrect discriminator or high voltage settings

Every scintillation counter must be calibrated for each radionuclide to be counted on the system. High voltage settings can drift because of photomultiplier tube age or circuitry problems. Obtain a gamma spectrum and determine if the high voltage and discriminator settings have changed. Frequently, quality control is performed with a radionuclide other than that used for specimen counting and the settings may be inadvertently overlooked during subsequent sample counting with a different radionuclide. For example, a patient who received I-123 for a thyroid uptake was counted in our laboratory on Co-57 settings, the radionuclide that we use for scintillation counter quality control. This error yielded a falsely low uptake value in a clinically hyperthyroid patient. Investigation disclosed that an incorrect discriminator setting was used when the patient was counted. As a safeguard measure, and also for more comparable quality control data, we have changed our quality control source for our scintillation counter to Te-123m, which has an energy of 159 keV, and consequently is counted with discriminator and high voltage controls as those needed for I-123. Make sure to double-check all settings used.

b) Contamination

Sample or container and instrument contamination are frequent occurrences as well, particularly with well-type counters. Decontamination sprays or liquids can be used to wash extraneous contamination from surfaces and the sample can be recounted. If sample counts still remain inordinately high, the sample should be evaluated on a multichannel analyzer system and recounted at an appropriate time depending on the nature of the contaminant radionuclide found within the sample.

c) Intrinsic malfunction

Notify the service personnel.

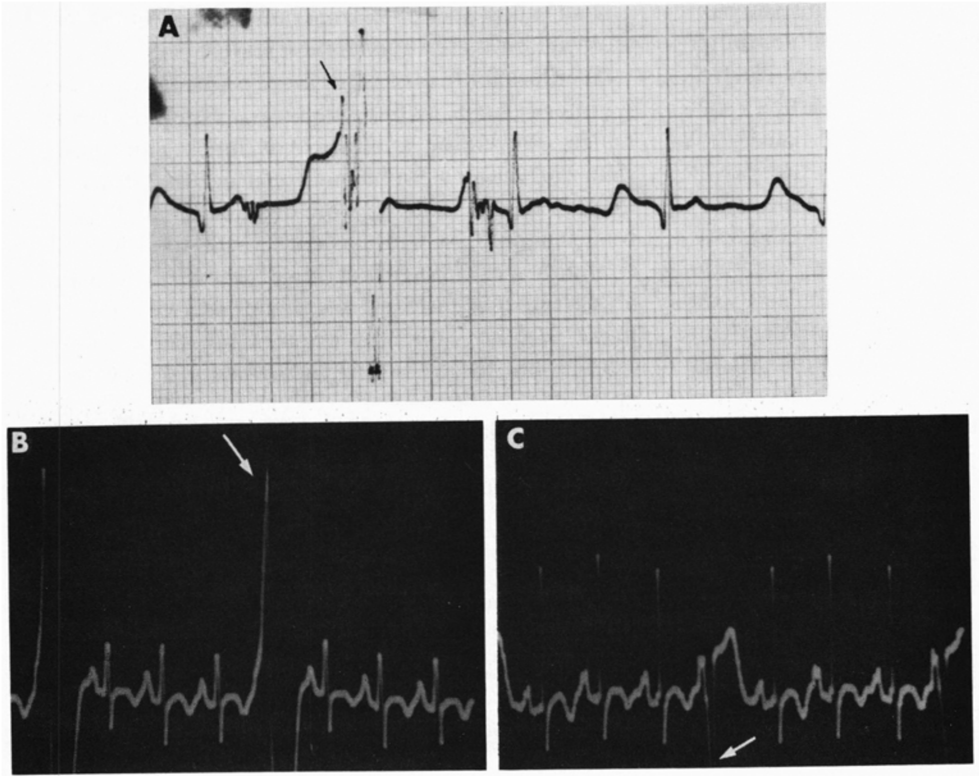


FIG. 5. (A) Effect of ECG electrode placement. Artifact (arrow) is caused by a loose electrode. (B) Frequent PVCs (arrow) are magnified by electrode placement. (C) Reversal of leads and change of electrode placement changes the polarity of the PVCs (arrow).

IV. Computer Systems (Table 4)

A. Problem: Data acquisition/playback problems

1. Causes and solutions

a) Faulty connections

Check all coaxial cable connections for proper contact. A loose fitting will create intermittent data acquisition problems.

b) Improper environmental conditions

As with the scintillation camera systems, computers require an ambient temperature of 68–70° F with a non-condensating environment of 40–45% humidity. Each integrated circuit (IC) produces a finite amount of heat. Since a computer system is composed of hundreds of ICs, it will produce a considerable amount of heat that is released through outlets or vents. Make sure that the computer and these vents have an unrestricted air flow and that tables, cabinets, etc, have not been inadvertently positioned against the unit. Humidity considerations are extremely important since moisture can cause a considerable amount of damage as well as faulty operation. Condensation on the disks or diskettes can also cause a system to "crash" and result in costly service repair. If a disk is cold, or cool to the touch, allow the disk to warm to room temperature before inserting it into the computer drive to prevent condensation in the disk drive.

c) Dirty disks, diskettes, or tapes

TABLE 3. Scintillation Counter Check List

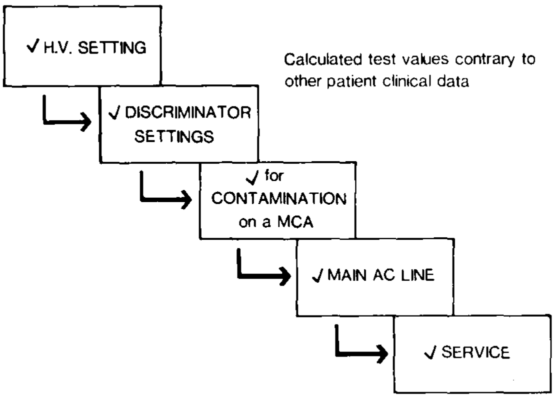
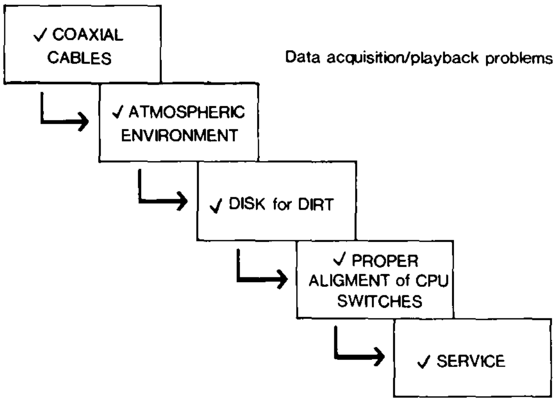


TABLE 4. Computer System Check List



Next to environment, cleanliness is probably the next most important consideration for proper computer function. Since data are transferred to disk by electromagnetic interactions, any dirt or dust particles can interfere with this magnetic field and in the read/write process; erroneous data transfer or no data transfer at all can result. A disk head literally flies over the surface of a disk cartridge at a very close proximity to the disk, usually about 1 μm. Fingerprint smudges, cigarette ashes, and pieces of hair are larger than 1 μm so it can easily be seen how important stringent cleanliness can be (*7*). All disks, diskettes, and magnetic tapes should be stored in protective covers or in sealed cabinets when not in use, and periodic cleaning maintenance should be established with the appropriate service personnel. Continuing to use a dirty disk in a computer system can result in a system "crash", a repair that necessitates lengthy computer down-time for repair and considerable expense. If acquisition problems can be pin-pointed to a specific disk or diskette, that unit should be set aside and not used until evaluated by the appropriate personnel. Computer filters and disk drive heads should also be cleaned at predefined intervals to ensure proper equipment function.

d) Incorrect central processing unit switch placement

Check all toggle switches and power/run controls for proper alignment.

e) Improper computer image size

Proper sizing and placement of the camera image within the computer's acquisition matrix is necessary for image consistency. Proper sizing is obtained by adjusting the gain and balance controls in the camera computer interface. Adjustment of these controls do require finesse but, with care, can be properly adjusted by a skillful technologist.

f) Intrinsic computer malfunction

If all of the above sets are tried and do not correct the problem, notify the appropriate service personnel.

Troubleshooting of equipment problems is very closely inter-related with preventative equipment maintenance. Preventing a problem is much more desirable than correcting a problem once it occurs. Many equipment problems, once they are diagnosed, can be rectified by a technologist with basic electronics knowledge and common sense. Each individual user must be aware of all agreements stated in his or her service contracts to make sure no violations occur. Once these have been established, the technologist can proceed to follow the guidelines set forth in this article. Since the goal of any nuclear medicine operation is quality work in the most cost-effective way, troubleshooting is an integral part of that operation.

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