GLOBAL RESEARCH ANALYSIS

ISSN No 2277 - 8160

Listed & Indexed with

ISSN Directory, Paris



Multi-Subject Journal

Volume : 1 | Issue : 2 | July 2012 | ₹ 250/-

GLOBAL RESEARCH ANALYSIS

ISSN No 2277 - 8160

GLOBAL RESEARCH ANALYSIS

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Cell : +91 98247 02127, 8866 00 3636

INDEX

Sr. No.	Title	Author	Subject	Page No.
1	Application of One Way ANOVA and Tukey's HSD Post Hoc test to Ecological Data	T B Mruthunjay, Dr. Shankar P Hosmani	Biotechnology	1-3
2	"New Area and Management Through Value Based"	Dr. Pankaj. K. Trivedi	Commerce	4-5
3	E-Supply Chain Strategies	Dr. Vipul Chalotra	Commerce	6-7
4	Socio-economic and Cultural factors in health, health services and prevention: An over view	Jaibarath Mageshkar	Economics	8-9
5	A Discriminant Analysis on Demographic Factors and Satisfaction Level of Credit Card Users in Coimbatore City	Dr.Malarvizhi.V	Economics	10-12
6	Effects of Socio-Cultural Determinants on Fertility	Prof. Dr. K.J. Thankachan	Economics	13-15
7	"Need of Effective Communication Model in Teaching Learning Process"	Dr. Mujibul Hasan	Education	16-18
8	Awarness on Special Education for B.Ed Students	Dr. S. K. Panneer Selvam	Education	19-20
9	Quality Improvement in Elementary Teacher Education	Ramesh B. Sakhiya	Education	21-22
10	Mobile operating system: A Case study on Symbian and Android	Vidyasagar S.D.	Engineering	23-25
11	IIR Filter Design to remove noise from ECG signal	Aarti J Patel	Engineering	26-28
12	Assessment of Godavari River Water For Sustainable Utilization.	I. B. Ghorade, S. S. Patil, M.D. Wagh	Environment Science	29-32
13	Shiksha, Saksharta aur Media	Dr Subodh Kumar	Journalism	33-34
14	Television Viewing Behaviour of Rural Women	Dr. H.Ramakrishna	Journalism	35-36
15	Female Foeticide and PNDT Act: Issues and Challenges	Dr. Anu, Dr. Pawan Kumar	Law	37-38
16	Product Invasion from foreign Competitors Whether Indian Product will win this Competition?	Dr. Ashish Singh	Management	39-40
17	"Role of State Wise Employment Exchanges on Condition That Employment In India."	Mr. Vimal P. Jagad	Management	41-43
18	A Study for The Growth of Micro, Small, Medium Service Enterprises Thorugh Tourism Development	Prof. Nikita Gupta, Prof. Parag Gadve, Prof. Farha Hussain	Management	44-45
19	To Study The Need of Capacity Building for Rural Tourism	Prof. Parag Gadve, Prof. Nikita Gupta, Prof. Farha Hussain	Management	46-47
20	CRM and Information Technology	Prof KVSN Jawahar Babu	Management	48-49
21	Strategies for Seizing Rural Markets- A Checklist for Fmcg Firms	Prof KVSN Jawahar Babu, N Meena Rani	Management	50-52
22	Implementation of Adaptive Controller based on FPGA for Flow System	Ankit V Bhaiya, Prof. Vandana V. Patel	Management	53-55
23	"A Study of Evaluation of Operating Performance of Selected Mutual Fund in Global Era"	Mital R Menapara, Bhavesh P Chadamiya	Management	56-57
24	"Remarks on the Measurement, Valuation and Reporting of Intangible Assets"	Dinesh C. Dhoniya	Management	58-59

Sr. No.	Title	Author	Subject	Page No.
25	Corporate Social Responsibility: Micro and Macro level	Parul Jain	Management	60-61
26	Role of Management Schools in Transformation of Rural India	Dr. H.Ramakrishna	Management	62-64
27	A Study on Customer Experience in Modern Retail Stores with Reference to Big Bazaar, Hyderabad	N Meena Rani	Management	65-67
28	Impact of Satellite Television on Adolescent Girls of Silchar Town in Southern Assam	Dr Partha Sarkar	Mass Communication	68-70
29	Quality Assurance Procedure for Computerised Tomography Scanners(Test Followed In India)	Suresh Sukumar, Sushil Yadav	Medical Science	71-74
30	Magnetic Resonance Imaging of Routine shoulder protocols	Suresh Sukumar, Sushil Yadav	Medical Science	75-76
31	A Simple Teaching Module for Brain Sections: Integration of Traditional Teaching Methods and Modern Computer Technology.	Dr. Archana U. Shekokar, Vandana A. Tendolkar	Medical Science	77-78
32	Effects of Mand Training on Negative Behaviours and Verbal Behaviour Development: A Case Study	Prasanna V, Sunila John, B Rajashekhar	Medical science	79-81
33	Effectiveness of Videotaped/Photographs in Teaching Handling Techniques for Caregivers of Children with Spastic Cerebral Palsy	V.Guruprasad, KR.Banumathe, T. BalaKrishnan	Medical Science	82-84
34	Comparision of Thresholds of Single Frequeny and Muti Frequency Auditory Steady State Responses in Normal Hearing Adults	Sadanand Gore, Hari Prakash P	Medical Science	85-87
35	Clinical applications of Speech Evoked Cortical Auditory Potentials (SECAPs) in Pediatric Hearing assessment & Aural habilitation- A case report	Ayas Muhammed, Archana, Kishan, Hariprakash, Prajakta Prabhu	Medical science	88-89
36	Rudimentary horn pregnancy: A Case Report	Dr Ashwini Avinash Yelikar , Dr Vidya Vijender Ambatkar, Dr Kishore Hol, Dr G S Shekhawat	Medicine Science	90-91
37	A rare case: Typhoid fever with ARDS	Dr. Ramakrishna Ghubde, Dr. Archana Shekokar	Medicine Science	92-93
38	Motivation, Well-Being & Adjustment of Economic Downturn Survivors: An Empirical Study in a Manufacturing Industry	Vijaya.R, Dr.M.Y.Manjulat	Psychology	94-96
39	Diversity of cladocerans, copepods and ostracods of Kapsi Lake Kapsi, Akola (MS) India	P. P. Ade	Zoology	97-100
40	Study of macromolecular contents of different tissues of Channa punctatus under stress condition	Pooja S. Thakur	Zoology	101-102
41	Spider diversity of Katepurna Sanctuary District Akola (MS) India	Shegokar M.M.	Zoology	103-106

Volume : 1 | Issue : 2 | July 2012 • ISSN No 2277 - 8160

Research Paper | Medical Science

Quality Assurance Procedure for Computerised Tomography Scanners(Test Followed In India)

Suresh Sukumar Department of Medical Imaging Technology, Manipal University, Manipal

Sushil Yadav Department of Medical Imaging Technology, Manipal University, Manipal

ABSTRACT

In today's world of rapidly changing medical technology, it is important to maintain quality diagnostic information for medical professionals. However, it is equally important to minimize patient and personnel radiation exposure risks. Helical (spiral) computed tomography (CT), was one of the most significant developments in the field of radiography. This article will review the evolution of CT and the corresponding quality assurance program requirements; including quality control tests, and the test tools used to follow the guidelines set forth by AERB. These guidelines must be maintained by medical facilities across the country in order to continually provide patients the quality medical information they expect, and minimum radiation dose they deserve. CT has made rapid developments within the past 10 years, and continues to be an integral part of the field of radiologic special imaging. Quality assurance testing assures periodic performance testing of the CT scanner and comparison to standards.

KEYWORDS: Computer Tomography, Qualti Assurence, AERB

INTRODUCTION

This manual has been established to document the functions of various Departments and individuals in maintaining quality assurance in diagnostic and therapeutic radiology. The purpose of a quality assurance program is to provide a quality image and reduced radiation exposure to both patients and workers to a level As Low As is Reasonably Achievable (ALARA). This is achieved through a formalized program of Quality Control testing, documentation of the efforts, evaluating the records and correcting programs as they are detected.

TESTS TO BE CARRIED OUT FOR THE TYPE APPROVAL OF THE COMPUTED TOMOGRAPHY(CT) SCANNER

1.Alignment of Table to Gantry

Test Frequency: Initially and Monthly

Standard: ±5 mm

Purpose: To ensure that long axis of table is horizontally aligned with a vertical line through the scanner rotational axis.

Principle: Misalignment can cause image artifacts with large patients if patient extends out of the sampled area.

Tools needed: Tape measure and adhesive tape. Optional - a plumb bob (string with a pointed weight on the end).

Procedure:

1. Place piece of tape on middle of tabletop, locate table midline with ruler and mark on tape.
2. With table and gantry untitled, extend table top into gantry to tape mark.
3. Locate vertical midline of gantry opening with tape measure across largest horizontal diameter or alternatively hang plumb bob from top midpoint of gantry opening. Mark gantry midline on adhesive tape on tabletop.

Interpretation: Measure horizontal inaccuracy from marks on adhesive tape. In absence of manufacturer's specifications, gantry midline should be within ±5 mm of table midline

2. Scan Localization Light Accuracy

Test Frequency: Initially and Monthly

Standard: ±2 mm

Purpose: This quality control test shows the congruence of scan localization light/laser and x-ray field scan plane. Patient anatomy to be scanned is often defined by scan alignment lights. Alignment lights may be located within the gantry at the slice plane, outside the gantry at a reference distance from the scan plane, or both. If both internal and external alignment lights are supplied, and are independently aligned, both should be tested.

Tools needed:

8´ X 11´ therapy localization film

Suitable rigid support for film backing plate

Adhesive tape and a sharp pin or needle.

Tape film to a suitable ridged support. Align the film to the long axis of the table, and raise the table to the head scan position. Turn on the internal alignment light and mark the location on film by piercing the film pack with a pin at several points along the middle of illuminated line. Scan the film pack at the inner light location using the narrowest slice setting: = 1.0mm. Reposition the film and repeat procedure for external light, but put a unique pattern of pin pricks near each illuminated line for easy identification. Scan the film pack at the external light location using the narrowest slice setting: = 1.0mm. Develop the film. Measure alignment error from pierced hole in processed film to midpoint of the radiation field. Error should not exceed ±2.0mm. Test results must be documented and maintained for at least one year.

3. Table/Gantry Tilt

Test Frequency: Initially and Monthly

Purpose: To determine accuracy of tilt indicators and to ensure that specified tilt can be accomplished under clinical conditions.

Principle: Tilt indicators on gantry or table may not correspond to actual tilt or to that indicated on computer display. Some scanners may collide with the patient at extremes of tilt under some clinical conditions. Most scanners accomplish non orthogonal scan planes by tilting the gantry, but some angle the table. Most table-tilting systems angle the table relative to the horizontal plane; however, pivoting of the table relative to the vertical plane is also seen.

Tools needed: Carpenter's spirit level, protractor, adhesive tape, sheet of therapy localization film, film backing plate, and tape measure with millimeter ruling.

Tape film centered to side of acrylic plate, with film edge carefully aligned to edge of plate.

Lower table to body scan position.

For systems which tilt the gantry or table in vertical plane: Align plate with long axis of table, parallel to vertical plane (verify with spirit level).

Fix in position with tape extending from table edge to table edge across top of plate.

For tables tilting in horizontal plane: Place plate flat on tabletop with plate edge aligned to table long axis; tape into position.

Move tabletop into gantry opening: center plate to alignment light. Expose the film at inner light location using narrowest slice setting at ~ 50-100 mAs, 120-140 kVp. Tilt gantry (table) to one extreme from operators console: record angle indicated on gantry (table) and operators console, repeat exposure. Measure gantry clearance from closest point on gantry to table midline. Tilt to opposite extreme, record indicated angles, repeat exposure and clearance measurement.

Interpretation: Measure tilt angles between density lines on processed film using protractor; express angles relative to density line from untitled position. In absence of manufacturer's specifications, tilt inaccuracies should be less than 3°; console and gantry angle indicators, however, should agree exactly. Ideally, gantry clearance at the extremes of tilt should permit the scanning of at least a 30 cm patient.
4.Table Position Indicator Accuracy

Test Frequency: Initially and Monthly

Standard: ±2 mm
This test assesses the amount of relative table displacement between successive scans by measuring the actual displacement the table traveled between scans. The CT operator must be able to accurately move patients to the indicated distance between scans from the operator control console. The true position of the bed should agree to within ± 2.0 mm of the indicated position.

Tools Needed:
30 cm. ruler

8´ X 11´ therapy localization film

Suitable ridged support for film backing plate

Measurements taken with a mass of 100 kilograms or less on the patient table

To perform this procedure, tape film to a suitable rigid support and set scan width to 5mm. Scan the film at a typical starting position. Then from the operator control console increment the tabletop 100mm in a positive direction and scan the film. Then repeat incrementing the table top another 100mm and scan the film again. Repeat incrementing the table top another 100mm and scan the film again. Process the film and measure the distance between the slices, measuring from the beginning of the first slice to the beginning of the next slice, check the distance between the other consecutive slices. Repeat the same procedure in the negative direction. Test results must be documented and maintained for at least one year.

5.Scan Increment Accuracy
Test Frequency: Initially and Monthly
Standard: ±1 mm
This test determines of the deviation of indicated versus actual scan increment. Under computer control from operator's console the patient table must be able to accurately and reproducibly move the patient to any indicated position in the scan field. Accuracy is critical since it influences the multi-scan dose and determines relative locations of image sections. If no manufacturer's procedure is available, then use the procedure below.

Tools needed:
Adhesive tape and tape measure with millimeter ruling.

To perform this procedure, tape a ruler along the tabletop edge, near the foot end of the table. Tape the end of the paper clip onto the table frame opposite the middle of the ruler with the pointer directed at ruler midpoint. Zero table position. Place on the table 70-100kg, or have an assistant lie on the table. This gives the table the weight it needs to simulate a patient. From control console, note the table position. Under computer control, move the tabletop 300mm in one direction, and then back to the original position. The tabletop should go back to the original position. At this point, measure the difference, if any indicated by the pointer and the ruler. Repeat this measurement again in the opposite direction to be sure that the measurements are consistent. Record results.

6.Measurement of Operating Potential
Tools Needed: KVp meter with the Ionization Chamber

Purpose: To ensure that the X-ray generator is producing the kVp as selected.

To determine the output of the x-ray tube at various kVp settings and at various mA stations..

Frequency: Semi-Annually

Procedure:
1. Place kVp meter on the tabletop and at the ISO center of the Gantry.
2. Collimate the beam to the active area of kVp meter.
3. Set the starting kVp, mA and time stations.
4. Evaluate kVp accuracy at various kVp stations and at various mA stations with fixed Scan time.
5. Make scan and record the display value of kVp meter output.

Acceptance Limits:
± 2kVp of indicated for < 30 kVp,
± 3kVp of indicated for 31 – 100 kVp, and
± 6kVp of indicated for > 100 kVp

7. Measurement of mA Linearity

Tools Needed: KVp Meter with Ionization Chamber

Purpose: To assure linearity or consistency in µGy/mAs between mA stations to achieve uniform results for the same mAs.

Frequency: Semi-Annually

Procedure:
1. Set KVp slice thickness and Scan time and keep all of the scan parameters constant except mA settings.
2. Keep the KVp meter at the center of the Gantry.
3. Record exposures using various mA stations and their adjacent stations, keeping kVp constant.
4. Record exposures as µGy as output.
5. Calculate the µGy/mAs for various mA settings.
6. Calculate the Coefficient of Linearity(COL),it should be with in ±0.05

8.Measurement of timer Linearity

Tools Needed: KVp Meter with Ionization Chamber with the time and Exposure parameters.

Purpose: To assure linearity or consistency in µGy/mAs between various scan timing.

Frequency: Semi-Annually

Procedure:
1. Set KVp slice thickness and mA constant except scan time settings.
2. Keep the KVp meter at the center of the Gantry.
3. Record exposures using various Scan timings keeping kVp constant and mA Constant..
4. Record exposures as µGy as output.
5. Calculate the µGy/mAs for various scan time settings.
6. Calculate the Coefficient of Linearity(COL),it should be with in ±0.05

9.Measurement of Output Consistency(kVp)

Tools Needed: KVp Meter with Ionization Chamber with the time and Exposure parameters.
Purpose: To assure the kVp output consistency is maintained.
Frequency: Semi-Annually.

Procedure:
1. Set the mA, slice thickness and Scan time at the standard value.
2. Keep the kVp meter at the center of the Gantry rotation.
3. Set the kVp and do the scan and record the readings in the kVp meter
4. Repeat the Scan for 4 more time with the same set up and record the readings.
5. The above process should be repeated for the various kVp settings.

6. Calculate the Mean value and Coefficient of Variation.
7. The tolerance limit for the COV should be ±0.05

10.FILTRATION OR HALF-VALUE-LAYER CALCULATION
TOOLS NEEDED: KVp Meter with Ionization Chamber, and Standard Al Filters

Purpose: To determine the amount of inherent filtration in an X-ray tube at 100 kVp in terms of aluminum equivalent and to assure that the amount of filtration is in compliance with AERB Regulations

Frequency: Annually

Procedure:
1. Use General Protocol and remove any filters that can be casually removed.
2. Set the X-ray equipment at 100 kVp, 100 mA, 0.1 sec. Or any other similar setting that gives about 300 to 400 mR with no filters added.
3. Initialize kVp meter and position it at the center of Gantry rotation.
4. Take two or three exposures and verify using the computer software that the kVp, mA and time output is within acceptable limits for the selected settings.
5. Take another exposure adding the minimum HVL (Half Value Layer) of aluminum and record it. The output value must be greater then minimum HVL aluminum set.
6. Take two more exposures without filters to determine the precision of output measurements. Calculate the HVL using the equation: -1/X (ln I/Io) =μ

where:

I= final intensity, after adding filtration

Io= initial intensity with no filtration.

X= thickness of aluminum filter added.

μ= ln 2/HVL

Solve the equation for HVL to obtain the HVL (beam quality).

Acceptance Limits: For 100 kVp, a minimum of 2.7 mm Al HVL is required for certified equipment. For uncertified equipment, State law requires 2.5 mm Al for equipment that operates above 70 kVp.

11.Measurement of Computed Tomography Dose Index(CTDI)
Standard: ±20% of the quoted Value(Expected)

Tools needed: Head and body CT dosimetry phantoms CT air ionization detector, and acrylic sleeves to lit within CT phantoms, adhesive tape and phantom alignment rod(Lucite Rod)

Procedure:
1. Place CT head dosimetry phantom on the patient table and align phantom axis parallel to scan rotational axis with slice plane through mid length of phantom.
2. Put alignment(Lucite Rod) rod in central phantom hole. Take standard head scan with a slice width of 5-6 mm, look at image to see that all three holes in alignment rod are clearly seen, and realign phantom if necessary.
3. Tape phantom in position when aligned.
4. Select a technique which represents an average patient, and record the factors used (i.e. kVp, mA, sec, slice thickness [in mm])
5. Put ion chamber in hole near surface (1 cm depth hole) corresponding to maximum dose point. If rotation angle of scan mode to be tested is <360°, then rotate phantom so that one dosimeter position (at 1 cm depth) is aligned with midpoint of scan arc. If scan angle is >360° (overscan) then position dosimeter location at middle of overscan region. If this position is unknown, take several measurements with chamber at different positions. Note that with scanners with continuous rotation capability, the maximum dose position varies from one scan to the next.
6. Record the exposure (mR), and the time (in second).
7. Measure exposure integrals for all standard head techniques, at all calibrated kVp settings, and with any operator selectable beam filter combinations (appropriate for head scanning).
8. Also measure for all available slice widths.
9. Repeat for all holes (5 holes) in the phantom with the initialized MDH in the Pulse Exposure Mode
10. Repeat with body and infant phantoms as appropriate, using above alignment procedure.

Weighted Average CTDIw=CTDI(CTDIw)=1/3CTDIc+2/3CTDIp
mGy/mAs

Interpretation: MSAD(Multiple Scan Average Dose) values should be determined for all standard scan conditions, and for any variable which might be expected to influence dose. In interpreting data determine whether parameter changes produce the expected result on dose, e.g., a linear change with mAs or slice width. Ensure that all conditions are comparable when comparing with manufacturer's specifications. The MSAD, and CTDI must be consistent with averages and deviations as reported in AAPM Medical Physics, Monograph # 20, p.918- 921or as listed in the manufacturers CTDI specification of 20% for the thickness > 3 mm

Tolerance: value (Expected): ± 20% of the quoted
± 40% of the quoted value (maximum)

12.RADIATION LEAKAGE TEST
Measurement of Leakage levels in Various location of CT Room
Standard: Leakage radiation Level at 1meter from the Focus should be ≤115mR in 1 Hour.
Tools Needed: Survey Meter with the Scintillation Counter and Measuring Tape.

Procedure:
1. Set maximum kVp and standard scan time and mA setting with maximum slice width.
2. Measure the distance from the Centre of rotation of Gantry and mark point for 1m, 2m at the front of the Gantry on the table top.
3. Do the scan by keeping the survey meter at the places marked.
4. Record the readings in mR/Hr.
5. Do the same measurement at the back of the Gantry.
6. Do the scan for each point with survey meter in place.
7. Record the readings.
8. Calculate the Max leakage from the above reading with following formula.
9. Max Leakage=

180mA minx-------Max Leakage mR/Hr
60X ------mA used for the Measurement
Interpretation: From the above calculation the max Leakage per hour should not be more than 115mR

13.High contrast resolution
Phantom: high contrast resolution pattern as shown in image

Measurement: on the CT scan determine the smallest row of the hole in which all the hole are seen clearly

Expected result: - Most modern CT scanner have a high contrast resolving power slightly smaller than 1mm by using a typical head image technique. Therefore thry will be able to visualize a complete set of hole in some of the rows in the range of 0.75mm to 1.00mm

Acceptance limit ; - this baseline number should be established when the CT scanner is working well by scanning the phantom and notice the smallest set of hole that can been seen this initial measurement become the baseline for the future

Tolerance : At 10% contrast difference the size of the bar/hole pattern that could be resolvable should be 1.6 mm (» 3.12 lp/cm).

14.Low contrast Resolution
Phantom : low contrast resolution pattern in imaging phantiom. A quick and easy test pattern of low contrast test object consist of a series of hole (2 to 8 mm)drilled in polystrene.the contrast difference between the hole is .5mm

Measurement : on the CT image, determine the smallest row of hole in which all hole can be seen clearl.

Acceptance limit ; - this baseline number should be established when

the CT scanner is working well by scanning the phantom and notice the smallest set of hole that can been seen this initial measurement become the baseline for the future

Tolerance: 5.0 mm at 1% contrast difference (minimum) 2.5 mm at 0.5 % contrast difference (expected)

Compilation of QA test results of Computed Tomography equipment

Sr. No.	Parameters tested	Specific values	Measured values	Tolerance	Remarks
1	Alignment of table to gantry			±5 mm	
2	Gantry tilt			±30	
3	Table indexing accuracy (mm)			±2 mm	
4	Slice thickness (mm)			±1 mm	
5	Accuracy of Operating Potential (kV)			±2 kV	
6	Accuracy of Timer			< 10 %	
7	Linearity of tube current (CoL)			± 0.1	
8	Reproducibility of output (CoV)			CoV < 0.05	
9	Radiation dose test CTDI –(mGy/100 mAs) at 120 kV			± 20 %	
10	Low contrast resolution			5.0 mm at 1% contrast	
11	High contrast resolution			3.12 lp/cm	
12	Radiation Leakage level from X-Ray tube housing 140 kV at 100 mA			< 1mGy in one hour	

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GLOBAL RESEARCH ANALYSIS

Multi-Subject Journal

Editor,

GLOBAL RESEARCH ANALYSIS

3, SUHANA, Nr. Ruby Apartment,
B/h NID, Rajnagar Circle, Paldi, Ahmedabad - 380007

Printed at Unique Offset, Novatsing Rupam Estate, Opp. Abhay Estate, Tavdipura, Shahibaug, Ahmedabad

Designed By : AdVoice Inc. +91 9824484447