5.2 ASSESSMENT OF X-RAY TUBE LEAKAGE RADIATION AND X-RAY TUBE OUTPUT TOTAL FILTRATION

5.2.1 Task

The bremsstrahlung produced by the X-ray tube has a continuous spectrum, limited by the set kVp and spreads all around the X-ray tube. The useful part of the radiation is directed to the patient through a collimator with Light-Beam-Diaphragm. The tube housing is made of lead in order to absorb all radiation, which is not directed at the patient. The amount of radiation, which has “leaked” from the housing should be minimal (its amount being regulated by the National Radiation Protection Legislations).

A substantive part of the bremsstrahlung used to produce an X-ray image, is low energy radiation, which absorbs in the human body and does not reach the X-ray film. Part of this useless and harmful radiation is absorbed by the tube glass envelope, cooling oil, etc. (called inherent filtration) plus some additional thin Aluminum plates normally attached to the Light-Beam-Diaphragm (added filtration). The combination of these filtrations is called the Total Filtration of the X-ray tube output. The ICRP has recommended the total filtration for normal diagnostic work (above 70 kVp) to be equivalent to not less than 2.5 mm Al. The Total Filtration (TF) is assessed by measuring the Half-Value-Layer (HVL) of the X-ray beam at a known kV, followed by an estimation process based on calculations.

Approximate time for performing the task - 6 hours

5.2.2 Competencies Addressed

Understand and measure the X-ray tube beam filtration and housing radiation leakage.

5.2.3 Equipment and Materials

At least 6 big X-ray cassettes (30 x 40 cm) loaded with films.
X-ray film Developing facilities.
Electrometer with two ionisation chambers:
    a small one ~6 cc and a big one ~1800 cc
At least 4 Al plates (approx. 10 x 10 cm, 1 mm thickness).
At least 2 Al plates (approx. 10 x 10 cm, 0.5 mm thickness).
Data for estimating the Total Filtration of the X-ray beam (see Reference).

5.2.4 Procedures and Measurements

5.2.4.1 For Assessment of X-ray Tube Leakage Radiation

Close the X-ray tube diaphragm and place the tube down on the X-ray table.
Surround the X-ray tube with at least 6 big X-ray cassettes with films, forming a closed volume (cubicle) around the X-ray tube housing (number the films).
Perform a heavy exposure (according to the X-ray unit possibilities) - for example 120 kV/200 mA/1 sec.
Develop the films and identify the dark places on the films.

Place a large volume ionisation chamber at the places, where the films are most dark, 10 cm from the tube housing, and repeat the heavy exposure.
Repeat the measurement at other places around the tube housing and record the values.

5.2.4.2 For Assessment of X-ray Tube Output Total Filtration
Place the small ionisation chamber 1 m from the focal spot.
Make one exposure at ~80 kVp, and approx. 40 mAs. Record the exposure (80 kV is the recommended energy for HVL measurements).
Place a 1mm Al plate between the X-ray tube and chamber. Repeat the exposure.
Add another 1mm Al plate to the previous filtration, repeat the exposure and record the result.
The procedures above are repeated until the recorded exposure is less than half the exposure without additional filtration.
Repeat the first exposure (with no Al plate) and record the exposure (this is to check that the machine parameters have not drifted during the measurements). Take the mean of the first and last measurements as +0mm Aluminum

Added Al (mm)	Set kV (~80)	Set mA	Set msec	Set mAs (~20-40)	Meas. exp (mGy)	Exp.decr. (%)
+0mm Al	80					100
+0mm Al	80					100
+1mm Al	80					
+2mm Al	80					
+3mm Al	80					
+4mm Al	80					<50

5.2.5 Calculations

5.2.5.1 For Assessment of X-ray Tube Leakage Radiation
Calculate the dose rate of the measured leakage radiation exposure.
Compare the calculated value with the recommended limit of 1 mGy/h @ 1m, (26 µGy per 1 sec @ 10 cm).

5.2.5.2 For Assessment of X-ray Tube Output Total Filtration
Calculate the percentage decrease of the exposure, measured in 5.2.
Plot the percentage decrease against the mm of Al additional filtration (a suitable software program can be used for the purpose, for ex. EXCEL).
Assess the HVL from the plotted curve as the mm Al, corresponding to 50 % decrease of exposure.
Assess the TF corresponding to the measured HVL, using the Reference Tables for the specific X-ray tube.
Compare the value received with the recommended TF.

5.2.6 Observations, Interpretations, Conclusions

Comment on the distribution of leakage radiation around the X-ray tube housing (from the films and the measurements).

Locate the Anode from the leakage radiation (comment on the stem radiation).

Observe the labeling of the X-ray tube inherent and added filtration (the added filtration to the LBD must be fixed!).

If possible compare the leakage radiation and TF for two different X-ray tubes.

5.2.7 References

IPSM Report 64 - Data for Estimating X-ray Tube Total Filtration.
Equipment for Diagnostic Radiology, E. Forster, MTP Press, 1993
Imaging Science and Protection, M.Thompson, ,J. Hall, M.Hattaway, S.Dowd, Saunders Co, 1994

Verification

Signature and date by the trainer:

Name of the Trainee:____
Comments:____
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Date:____________Trainer's sign:___________________________________

5.3 ASSESSMENT OF X-RAY TUBE OUTPUT PARAMETERS

5.3.1 Task

Assessment of X-ray Tube Output Consistency; Output variation with mA and with kV; Linearity. Assessment of the Focal spot size and the X-ray/Light beam alignment.

Approximate time for performing the task - 2 days.

5.3.2 Competencies Addressed

Understanding and measure the X-ray tube output parameters, focal spot size and LBD alignment. Seasoning of the X-ray tube.

5.3.3 Equipment and Materials

Electrometer with ionisation chamber ~ 6 cc.
kVp noninvasive meter (e.g. Keithley or RMI).
Focal spot test tool (e.g. RMI 112 B).
Collimator and beam alignment test tool (ex. RMI 53-62).
18x24 cm cassette (loaded with film).
Black film envelope.
X-ray film Developing facilities.
Tape measure.
Calculator.

5.3.4 Procedures and Measurements

5.3.4.1 Warming up of the X-ray tube

N.B. Before starting measurements the X-ray tube has to be warmed up (seasoning of the tube). For this, a minimum of three warming exposures have to be performed:

1. about 50 kV, about 50 mA and about 100 msec
2. about 50 kV, about 100 mA and about 200 msec
3. about 70 kV, about 100 mA and about 200 msec.

The minimum interval between the exposures has to be more than 1 minute.

5.3.4.2 Assessment of X-ray Tube Output Consistency

Position the ionisation chamber at 1 metre from the focal spot of the X-ray tube and at least 20 cm from any scattering object e.g. the patient couch. Collimate the X-ray beam to some 5 cm around the chamber.

Repeat the exposure a number of times on Broad focus and constant parameters (e.g. 80 kVp, 20 mAs) and record the measured air kerma for each exposure.

Repeat the measurements on Fine focus.

Focus	Set kVp	Set mA	Set msec	Set mAs	Measure kVp	Measure msec	Measure expos.	Air kerma
B	80			20				
B	80			20				
B	80			20				
B	80			20				
F	80			20				
F	80			20				
F	80			20				
F	80			20				

5.3.5 Assessment of X-ray Tube Output Variation with mA

Continue the measurements with the set up from 5.1.

Perform 4 exposures with constant kVp (e.g. 80 kVp) and exposure time, but with different mA (e.g. 50 mA, 100 mA, 200 mA, 400 mA).

Record the measured air kerma.

Focus	Set kVp	Set mA	Set msec	Set mAs	Measure kVp	Measure msec	Measure expos.	Air kerma
B	80	50						
B	80	100						
B	80	200						
B	80	400						

5.3.6 Assessment of X-ray Tube Output Variation with kV

(This can be done in conjunction with 5.4.4.2-5.4.4.4).

Continue the measurements with the set up from 5.1, but additionally place the kVp meter in the X-ray beam, in order to measure the real kVp's. The kVp meter should be at least 10 cm away from the ionisation chamber, to avoid back-scattered radiation hitting the ionisation chamber.

Perform at least 4 exposures with Broad Focus and with constant mA and msec (for ex. 200 mA and 100 msec), but with gradually increasing kVp (e.g. 60 kV, 80 kV, 100 kV, 120 kV).

Record the measured air kerma and kVp for each exposure.

Repeat the measurements with the Fine focus selected and possibly other kVp set (e.g. 50 kV, 70 kV, 90 kV, 110 kV).

Focus	Set kVp	Set mA	Set msec	Set mAs	Measure kVp	Measure msec	Measure expos.	Air kerma
B	60			20				
B	80			20				
B	100			20				
B	120			20				
F	50			20				
F	70			20				
F	90			20				
F	110			20				

5.3.7 Assessment of Focal Spot Size

Place an X-ray film in a black envelope on the patient table.

Place the focal spot test tool over the envelope with it's resolution pattern facing up and orientated parallel with the anode/cathode line of the X-ray tube.
As the tool is 6 inches high, the distance between the focal spot and the film in the envelope is adjusted to be 24 inches (if another tool is used, please refer to its manual).
Perform one exposure with the broad focus (approx. 50 kV and 40 mAs).
Develop and keep the film with the resolution pattern.
Repeat all above with the fine focus.

5.3.8 Assessment of the X-ray/Light Beam Alignment

Check visually the coincidence of the side light beam of the LBD with the middle of the bucky cassette tray.
Place a cassette with X-ray film (18x24 cm) on the patient table.
Set the distance between the film and the focal spot to 1 metre.
Place the test tool over the cassette (parallel to its edges).
Adjust the LBD collimator so that the light beam covers exactly the inner pattern of the test tool.
Perform an exposure with approx. 50 kV and 4 mAs.
Develop and keep the film with the image of the test tool.
Compare the irradiated black square on the film with the shadows of the inner pattern of the test tool and record its difference in mm.
Record the interposition of the shadows of the middle ring and point. (e.g. the point in the ring; the point out of the ring; the point on the ring's border, etc.).

5.3.9 Calculations

5.3.9.1 For Assessment of X-ray Tube Output Consistency

Calculate the Dose output consistency (%). This is the relation between the standard deviation and the average of the measured exposures (mGy) for each focus (100*STDEV/AVERAGE).
Compare the calculated value with the recommended limit of 5%.

5.3.9.2 For Assessment of X-ray Tube Output Variation with mA

Calculate the Specific Dose Output (mGy/mAs) for each exposure.
Plot each Specific Dose Output against the corresponding mA.
Comment on the (mGy/mAs)=F(mA) function.

5.3.9.3 For Assessment of X-ray Tube Output Variation with kV

Calculate the Specific Dose Output (mGy/mAs) for each exposure.
Calculate the kV^2 of the measured kVp for each exposure.
Plot each Specific Dose Output against the corresponding kV^2.
Comment on the (mGy/mAs)=F(kV^2) function.

5.3.10 Observations , Interpretations, Conclusions

Comment on the necessity of X-ray tube seasoning.

Comment on the effect of Dose output inconsistency on film quality.

Observe and comment on changes in the (mGy/mAs)=F(kV^2) function and changes in the linearity related with higher energies.

Describe the scientific base of the method for focal spot size measurement.

Look in the Image Database for different Test objects for focal spot size measurement and explain their difference.

5.3.11 References

IPSM Report 32 - part I - X-ray tubes and generators.
Manual for the Focal Spot Size Measurement Tool.
Technical and Physical Parameters for Quality Assurance in Medical Diagnostic Radiology, BIR Report 18, 1989
Equipment for Diagnostic Radiology, E. Forster, MTP Press, 1993
Imaging Science and Protection, M.Thompson, ,J. Hall, M.Hattaway, S.Dowd, Saunders Co, 1994

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