Radiation Hazards in Cephalometric Roentgenography*

J. B. Franklin, D.D.S.
Milwaukee, Wisconsin

Introduction

As in all experiments, while seeking one objective other interesting phenomena are brought into the picture. While experimenting with various kilovoltages up to ninety and decreasing milliampere-seconds of radiation, the factors of radiation hazards to both the patient and operator came to be considered. Quoting from Trout and his co-workers:[1]

"Because of the increased portion of the total population now receiving radiation from so many sources, it may well be that the long term effects of doses too small to produce an acute effect are important. Certain it is that in view of the increased use of radiation in all its forms to such a large percentage of our people, there is an obligation on the part of all who use radiation to subject the patient to as small a dose as is consistent with an adequate examination. *Anything that can be done to reduce the dose will be a step in the right direction.* The acute effects and well established principles to prevent them were the result of sad experiences to early patients and radiation workers. It is hoped that we will become aware of and establish limitations to prevent the non-acute and long term effects of small doses of radiation which at present appear to be *non-reversible* once the effect has been initiated and which may not be restricted in their influence to a single generation."

Those of us who work with x-ray equipment should be aware of the dangers of scattered or stray radiation. In addition, one should always be aware of the radiation hazards from primary rays to our patients. It is well to have some practical understanding of the energy or radiation[3,4] which is emitted from the x-ray tube. X-ray radiation is a form of energy which is obviously very useful but could be also very dangerous to those who are ignorant of its cumulative lethal potentialities.

The warning of Trout and his co-workers cannot be taken lightly. However, there are certain known safeguards from the effects of stray or scattered radiation, primarily regarding the position of the operator.

To better understand what is meant by such terms as primary radiation, useful beam, secondary radiation and scattered radiation, a definition of each term follows.

Primary Radiation:

Those x-rays which are given off the target of the x-ray tube and are emitted from the x-ray tube and tube housing through a window provided for that purpose.

Useful Beam:

That portion of the primary radiation which passes through an aperature, cone, cylinder or other device which directs the x-rays toward the subject

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being x-rayed.

SECONDARY RADIATION:

That form of radiation which is emitted by any matter which is being subjected to or irradiated with x-rays.

SCATTERED RADIATION:

A form of secondary radiation; especially that radiation which is deflected in direction while passing through matter.

We are all cognizant of the dangers of x-ray burns from primary or direct radiation. This type of burn proved disastrous and fatal to the early investigators. As a result of their sad experiences we have learned to be careful and to stay out of the path of these rays when operating x-ray equipment. However, we are not too informed regarding the risks involved from the effects of scattered or stray radiation. It should be remembered that the effects of x-ray radiation (primary or otherwise) on human tissue is *cumulative* and *irreversible*.

The radiation output of an x-ray tube is measured in roentgen units. What is a roentgen unit? According to Handbook 41 issued by U. S. Department of Commerce,[2] National Bureau of Standards: "The International Unit of quantity or dose of x-rays or gamma rays shall be called the 'roentgen' and shall be designated by the symbol 'r'. The roentgen shall be the quantity of x or gamma radiation such that the associated corpuscular emmission per 0.001293 gram of air produces, in air, the ions carrying one esu of quantity of electricity of either sign."

It makes no difference whether the x-ray radiation is primary, secondary or scattered, for they are all measured in roentgen units. It is merely a question of intensity per unit of time. Therefore, the National Bureau of Standards defines the maximum total dose to which any part of the body of a person shall be permitted to be exposed continuously or intermittantly in a given time as .0300 r or 300 mr per week.

The technic of cephalometric roentgenography is very well standardized. The usual exposure factors for lateral roentgenograms followed by many operators are 20 milliamperes (20 ma) for about 2½ seconds or (20 x 2½) 50 milliampere-seconds (50MAS) at about 60 kilovolts (60 KVP). At the present time I have varied the above technic by using a higher kilovoltage and a smaller milliamperage-second exposure; that is, 20 milliamperes at 3/10 second or 6 milliampere-seconds and 90 kilovolts. By this technic the patient has been exposed to considerably less radiation.

Knowing that 60 KVP at 20 MA will produce less radiation per unit of time than the high kilovoltage technic of 90 KVP at 20 MA, I subjected my technic and apparatus to a critical examination by the technical staff of the General Electric X-ray Corporation. The roentgen output of my x-ray machine and scattered radiation was measured with sensitive instruments by them as shown in Fig. 1, 2 and 3. To avoid subjecting any person to these radiation measurements a human skull was placed in the cephalostat. The radiation intensity (direct beam) is the radiation to which the patient is subjected. This was measured by the instrument (Fig. 1) at various distances from the tube. It should be noted that the direct beam radiation from the x-ray tube was limited to an area of 10 inches in diameter of the subject by using a steel cylinder 15 inches long and 3 inches in diameter as shown in (Fig. 4). It may seem, at first glance of Table I, that the high kilovoltage of 90 KVP at 20 MA subjects the patient to much greater radiation hazard than does 60 KVP at 20 MA. However, that is computed on per minute of time for both 90 KVP and 60 KVP at 20 MA. In the high

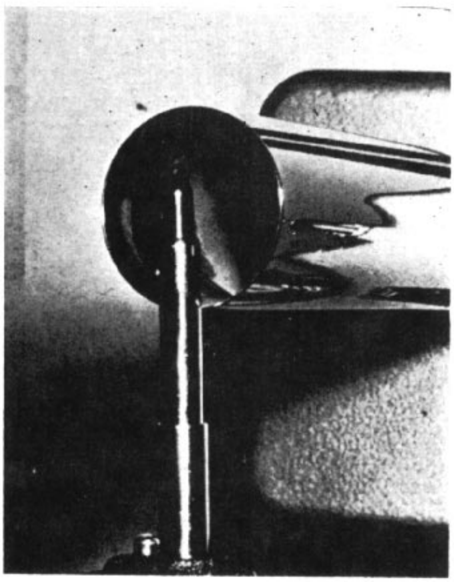

Fig. 1. Glasser-Seitz Radiation Meter measuring primary ray intensity in roentgens at the end of cylinder.

kilovoltage technic of 90 KVP at 20 MA, the time has been reduced from 2½ second to 0.3 second; that is, 50 milliampere seconds to 6 milliampere seconds. A comparison of the two (60 KVP & 90 KVP) total radiations, as indicated by graphs on Chart I, shows that the 90 KVP technic reduces the radiation greatly.

Using the same equipment in measuring scattered radiation, Fig. 5 indicates the various positions at which these readings were made. Scattered radiation is hazardous to the operator of the x-ray equipment. The positions show where the operator might be. Again, please note that per same unit of time, as shown in Table II, 90 KVP show a much greater intensity of scattered radiation. However, due to a reduction in the exposure time in the 90 KVP technic, the scattered radiation reaching the operator is very considerably less. It is also interesting to note that position 4, 45 inches to the side and parallel to the patient, is a safer spot than behind and along side of the x-ray machine. Again, referring back to the National Bureau of Standards permissible dose rate to which a person can be safely exposed, an examination of Fig. 5, Table 1, and Charts 1 and 2, can be used to illustrate how much radiation the operator and patient are being exposed to while taking lateral cephalometric roentgenograms.

Primary Radiation Hazards to the Patient

According to the radiation intensity readings of Table I, the patient is subjected to 5880 milliroentgens per minute if one uses the 60 kilovolt and 20 milliamperes exposure. In reducing the time exposure to 2½ seconds, the patient, as shown on Chart I, has been subjected to 245 milliroentgens per lateral roent-

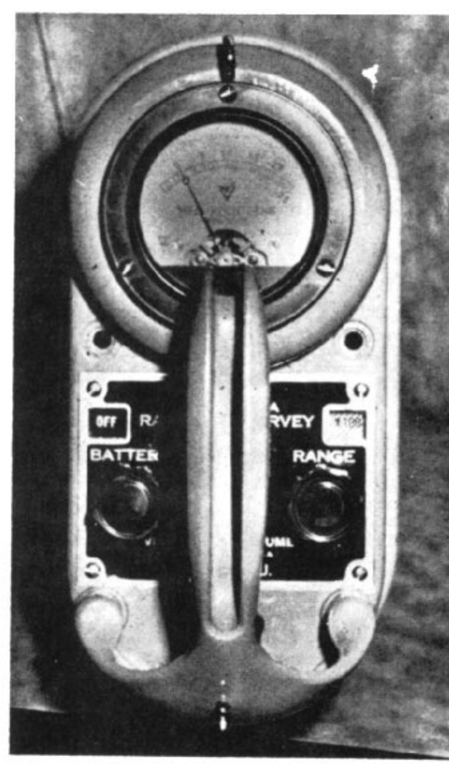

Fig. 2. Head of Radiation Survey instrument which records scattered radiation in milliroentgens up to 2500mr.

genogram, the total amount of exposure is 490 milliroentgens, or 190 milliroentgens in excess of the permissible dose of 300 milliroentgens per 48 hour week. It should be noted, however, that the 300 milliroentgen permissible dose rate is based on a 48-hour week for individuals who work in the areas of radiation. This may not apply to patients who are not continuously subjected to x-ray radiation. However, the untoward effect of x-ray radiation is still under study, and just to be on the safe side, it is advisable to wait at least ten days before retaking any roentgenograms, for it must be remembered that the effects of radiation are cumulative and *not* reversible.

In the high kilovoltage technic in cephalometric roentgenography, it is possible to reduce the milliamperage very considerably. In this technic I have used the exposure factor of 90 kilovolts—20 milliamperes at 3/10 seconds (90 KVP—20 MA x 3/10 = 6 MAS). With this technic less radiation is produced than with the 60 kilovoltage described in the foregoing paragraph. For an examination of Table I indicates that by using 90 kilovolts at 20 milli-

Fig. 3. Recording scattered radiation in position 1 (along side and behind X-ray machine) with a Radiation Survey Meter.

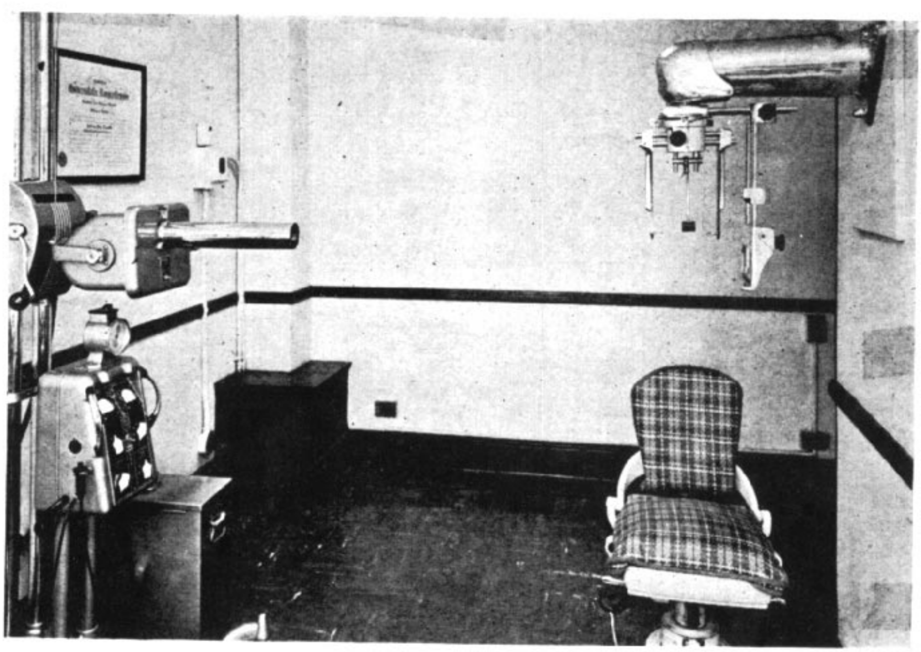

Fig. 4. Author's equipment.

amperes, the radiation intensity reaching the patient is 12.00 roentgens or 12,000 milliroentgens per minute. However, when the time is reduced to 3/10 second as shown on Chart I, the patient is subjected to only 60 milliroentgens, and if one takes two lateral roentgenograms the total milliroentgen exposure is only 120 milliroentgens. This is 180 milliroentgens *less* than the permissible dose of 300 milliroentgens per 48 hour week.

Secondary Radiation Hazards to the Operator

It should be remembered that secondary radiation, although less potent than primary rays, are dangerous if sufficient cumulative roentgens (beyond the permissible dose) are absorbed within a certain period of time.

TABLE 1

RADIATION INTENSITY — DIRECT BEAM

KVP	MA	*DISTANCE in Inches	ROENTGENS/ minute
60	20	18.00	60.00
90	20	18.00	121.00
60	20	57.50	5.88
90	20	57.50	12.00
60	20	60.00	5.40
90	20	60.00	10.88
60	20	63.75	4.78
90	20	63.75	9.70

Distances (inches)

*Focal-cone end	18.00
*Focal-patient surface (nearest to tube)	57.50
*Focal-patient centerline (cephalostat)	60.00
*Focal-film	63.75

To determine the amount of scattered or secondary radiation reaching certain areas where the operator might stand during the operation of the x-ray machine, readings were made at various positions shown in Fig. 5. First, a reading was made with an exposure of 60 kilovolts and 20 milliamperes, using the cylindrical limiting device. Then, a reading was made using an exposure of 90 kilovolts and 20 milliamperes. Finally, the *cylinder removed,* the secondary radiation was checked again. The results appear in Table 2. Please note the tremendous amount of radiation given off at all positions without the cylindrical limiting device. It is more than 2500 milliroentgens per hour. In fact, the secondary radiation produced went beyond the capacity of the instrument to record. This indicates, very obviously, that some restricting or limiting device should be used which limits the field of primary radiation and therefore reduces very materially the secondary radiation. This device could be a cone, diaphragm or cylinder.

Although an exposure of 60 kilovolts at 20 milliamperes gives off less secondary radiation per unit of time than does the 90 kilovolt technic (Table 2), the radiation hazard can be further reduced. Chart 2 shows readings taken at various positions (Fig. 5), comparing the secondary radiations given off by the x-ray machine being operated at 60 kilovolts — 20 milliamperes at 2½ seconds and at 90 kilovolts — 20 milliamperes for 3/10 second. At position 4, the 60 kilovolt technic registers .0208

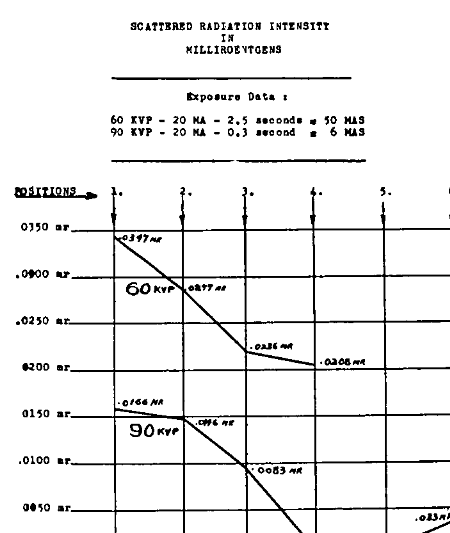

CHART 1

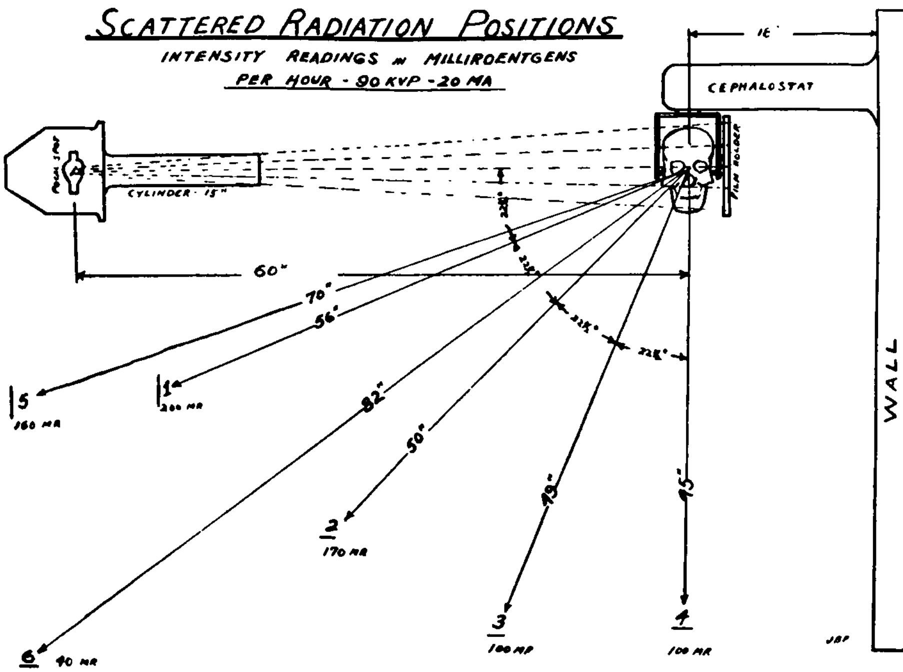

Fig. 5. Scattered radiation positions.

milliamperes per exposure while the 90 kilovolt technic produces only .0013 milliroentgens per exposure. That means, that at position 4, 90 kilovolts at 20 milliamperes exposure for 3/10 second presents a secondary or scattered ray radiation hazard to the operator one sixteenth as much as the 60 kilovolt, 20 milliamperes exposure for 2½ seconds. However, neither the 60 kilovolt or 90 kilovolt technic presents much secondary radiation hazard to the operator if he puts himself in position 4 as shown in Fig. 5. In this position he is parallel to the patient and about 45 inches away during the operation of the x-ray machine. Of course, the x-ray machine must be equipped with a limiting device which confines the area being radiographed to a 10 inch diameter.

Summary and Conclusions

1. There are known hazards from x-ray radiation in cephalometric roentgenography to both patient and operator. These hazards are the primary rays to the patient, and secondary or

TABLE 2

SCATTERED RADIATION INTENSITY

KVP	*MA*	*CONE*	POSITION 1	2	3	4	5	6
			Milliroentgens *per Hour*					
60	20	Yes	50	40	34	30		
90	20	Yes	200	170	100	100	160	40
90	20	No	(....................Greater than 2500....................)					

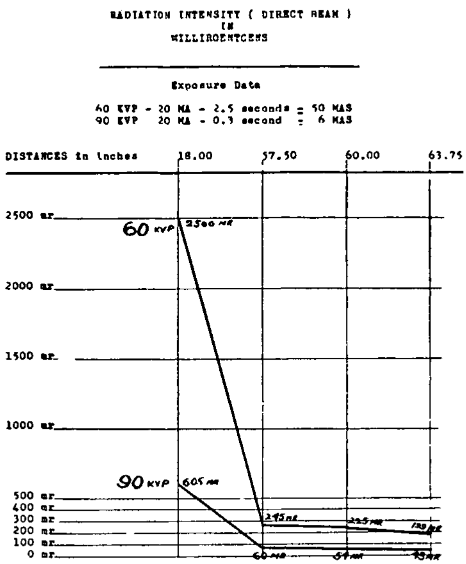

CHART 2

scattered rays to the operator, and can be measured with sensitive instruments devised for that purpose.

2. X-rays are measured in roentgen units, and the permissible dose rate to which a person can be safely exposed is .03 roentgens or 300 milliroentgens per week, a week being considered an eight hour day and six day week. In addition it should be remembered that the effect of radiation dosage is *cumulative* and *non reversible.*

3. It can be demonstrated that the high kilovoltage technic of 90 kilovolts—20 milliamperes for 3/10 second produces less radiation hazard than the usual method of 60 kilovolts—20 milliamperes for 2½ seconds.

4. The safest position for the operator, during the operation of the x-ray machine, is parallel to the patient being radiographed, and about 45 inches to the side and facing the x-ray machine.

208 *East Wisconsin Avenue*

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