SPECIAL REPORT

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ESSENTIAL RADIOLOGY: THE PAHO-WHO SYSTEM

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Health services in Latin America, the Caribbean, and developing areas around the world suffer from a severe shortage of radiology services. To help overcome this problem, PAHO and WHO have helped to develop a Basic Radiological System that offers good solutions to the fundamental training, safety, and cost problems involved. The following account describes their experience to date with that system.

Introduction

Within the Americas the nature of available diagnostic radiology services varies from country to country, locale to locale, and often reliable data about these services are lacking. However, as a general rule the following appears true of these services in Latin America and the Caribbean (1, 2):

1 In rural and marginal urban areas, most people do not have access to diagnostic radiology.
2 About half of the rural hospitals (defined as those with about 50 beds or less) do not provide diagnostic radiology services.
3 Some 80 to 90% of most countries' installed X-ray equipment is in the capital city or a few other large cities; very few X-ray machines are found in cities of 100,000 inhabitants or less.
4 Of the X-ray equipment that is installed, some 30 to 60% is not in working order.
5 Diagnostic radiology services in most big-city hospitals are saturated, and patient waiting times for X-ray examinations are long.
6 Many simple X-ray examinations are performed at university or referral hospitals because there is no other alternative.
7 Radiological diagnostic procedures are often conducted without due regard for proper indications, expected diagnostic yields, or adequate performance (including limitation of the patient's dose to optimal levels).

1 Condensed version of a document with the same title presented at the XIV Inter-American Congress of Radiology held on 12–17 October 1986 in Buenos Aires, Argentina.
In most countries, medical students have little or no experience with radiology services before beginning their professional careers. A prime need therefore exists to institute this training, and to include within it appropriate guidance on radiation protection.

These general conclusions are supported, among other things, by recent sample surveys conducted in five Latin American countries. Those surveys showed that a very high percentage of all X-ray examinations performed at referral and university hospitals are of a routine nature (3). (Many of these examinations should be conducted at local hospitals, but are not because the necessary staff and equipment are lacking or insufficient.) The surveys also found that only a small fraction of the patients given medical care at local hospitals received X-ray examinations. In some cases the percentage of patients receiving an X-ray examination at large-city hospitals was 15 times greater than the percentage receiving such an examination at local hospitals.

**The PAHO/WHO Basic Radiological System (BRS)**

In March 1975 a meeting was held at PAHO Headquarters in Washington, D.C., to define the type of X-ray system that could best serve the radiological needs of developing countries. Specifications developed at this meeting were improved and published by the World Health Organization in 1982 (4–8). The current WHO specifications for the Basic Radiological System's X-ray unit, plus accessories, may be summarized as follows:

1. Output of the generator should be high enough to (a) produce a minimum exposure of 0.5 milliroentgens in one second or less at a focus-film distance of 140 cm behind a water phantom of 30 cm thickness, and (b) produce 0.5 milliroentgens in less than 50 milliseconds at 140 cm behind a water phantom of 12 cm thickness.
2. The unit should have a rotating anode X-ray tube with a focal spot of less than one millimeter capable of handling 20 kW for an interval of 0.1 second.
3. The inherent filtration of the tube must be equivalent to at least 2.5 mm of aluminum.
4. The control panel should indicate the status of the electrical supply, the chosen kilovolt (kV) and milliampere (mA) values, and the object thickness. Only four kV values are possible: 120, 90, 70, and 55 kV. The minimum range of mA values, usable over the entire kV range, is 0.8–200 in 25 steps.
5. The design must ensure that the tube is always connected to the cassette holder in a rigid and stable way, permitting precise centering of the X-ray beam. A fixed-focus film distance of 140 cm must be used.
6. A stationary, focused lead/aluminum grid with 40 to 50 lines per centimeter and a ratio of 10:1 must be included.
7. The tube must be provided with an adequate collimator permitting restriction of the X-ray beam to the size of the films used. The collimator design must prevent any part of the patient from being closer to the X-ray source than 30 cm. The smallest format of the collimator must be no larger than 18 x 24 cm.
8 A movable pointer or other reliable system for centering the beam must be provided.

9 Film sizes should be standardized, and no more than four film sizes should be used. The cassette holder must accept at least the following three formats: 35.5 x 43 cm, 18 x 43 cm, and 24 x 30 cm.

10 The support provided for the patient must be rigid, must have an X-ray permeable top, and must be able to support a weight of 110 kg without appreciable distortion.

11 Strict time-temperature control must be used in the film processing. Darkroom equipment must be provided with the X-ray equipment.

12 A standard range of patient protection devices must be provided with the X-ray machine.

13 The cassette holder must incorporate a lead shield with a minimum thickness of 0.5 mm in the back wall.

14 At least one protective apron and one pair of gloves with a minimum thickness equivalent to 0.25 mm of lead must be provided.

15 A protective screen large enough to protect a standing operator must be an integral part of the control panel. The lead equivalent must be at least 0.5 mm, provided that the X-ray beam is never directed at the screen. A leaded glass window no smaller than 30 cm must be incorporated into the screen.

Experience with the Basic Radiological System (BRS). By agreement between the Government of Colombia and PAHO, testing of four BRS-type X-ray machines manufactured and donated by the General Electric Company was started in Antioquia in the fall of 1983. In one week, engineers from the General Electric Company installed four X-ray machines in three small hospitals serving rural areas and in one large health center serving a marginal urban area of Medellín (9, 10).

In less than two weeks, two assistant nurses and one physician from each hospital had been trained; and after five days of intensive work at Medellín, followed by one or two days of practical training in the local hospitals, the X-ray operators were obtaining reasonably satisfactory results with about 100 standard X-ray projections.

The Basic Radiological System includes not only appropriate X-ray equipment but also appropriate training for personnel and appropriate integration of radiological diagnosis into the health services system. Therefore, the field test included training of operators who were residents of the local community, as well as training of general medical staff members to evaluate the most common radiographic procedures required to diagnose local pathologic conditions. Other components of the system include an appropriate methodology for technical and professional support and referral, and also organization of an efficient supply and maintenance network. Supervision (another integral part of the system) was provided by a professor of radiology and by radiology residents from the University of Antioquia.

In 1985 four WHO BRS-type machines manufactured by the Siemens Company were installed in Nicaragua and one WHO BRS-type machine manufactured by the Philips Company was installed in Chile. In 1986 a second Philips machine was installed in Chile.
One of these Siemens machines was recently tested at the Mount Sinai Medical Center in Miami Beach, Florida. This machine is currently providing services at the General Hospital in Mexico City. Other field trials of the BRS have been organized in Africa, Asia, Europe, and the Middle East; the results of all these trials have been very good (11).

Overall, these generally favorable experiences have led to the following conclusions:

1. There are very few examinations that cannot be made by the BRS operator using the WHO Basic Radiological System Manual of Radiographic Technique (12) - a document that was especially prepared for use with the BRS X-ray machine. (The manual excludes contrast studies of the alimentary tract.)
2. The quality of the radiographs is excellent, even when judged by the standards of the most developed institutions.
3. An abbreviated training period of approximately two weeks is sufficient to teach the operator how to produce the standard radiographic projections, use the equipment, and apply the WHO manual, but is insufficient for proper instruction in darkroom techniques.
4. With the exception of some early problems in Nicaragua, no significant faults have been discovered in any of the WHO BRS-type machines.
5. Continuing on-the-job instruction by experienced radiologists and technicians is an essential part of the system and must be incorporated into any program utilizing the PAHO/WHO BRS.

**Premises Requirements for Installation of the BRS.** Generally, three rooms will be required for a BRS installation: the radiographic room, a darkroom, and a combination office-storeroom. The location should be chosen for easy patient access, as sufficient radiation protection is incorporated into the design of the machine or can be provided easily. Access to water supply and wastewater drainage facilities are required for the darkroom. The electrical supply needed is 5 amperes at 110 or 230 volts and 50 or 60 hertz.

Safe operation of a BRS-type unit installed at almost any location depends upon incorporation of enough lead into the back of the cassette holder to absorb almost all of the primary radiation after it passes through the patient. Current WHO specifications require a minimum of 0.5 mm of lead, enough to provide adequate protection at a design level of 10 milliroentgens per week for the conditions shown in Table 1.

**TABLE 1.** Design characteristics of BRS X-ray room for satisfactory radiation protection.

<table>
<thead>
<tr>
<th>Examinations per year</th>
<th>Area (m²)</th>
<th>Optimum room dimensions (m)</th>
<th>Distance to occupied area (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000</td>
<td>12</td>
<td>2.9 x 4.2</td>
<td>3.2</td>
</tr>
<tr>
<td>4,000</td>
<td>18</td>
<td>3.6 x 5</td>
<td>4.2</td>
</tr>
<tr>
<td>6,000</td>
<td>24</td>
<td>4 x 6</td>
<td>5.2</td>
</tr>
</tbody>
</table>
The first essential radiology or BRS specifications included the following minimum room dimensions:

- **radiographic room**: 18 m², minimum ceiling height 2.5 m
- **processing room**: 2 m², minimum ceiling height 2.25 m
- **office**: 8 m², minimum ceiling height 2.25 m

While the field trials demonstrated that it was possible to install a machine in less space (e.g., a radiographic room of about 10 m² with a ceiling height of about 2.2 m, a processing room of about 4 m², and no office space), the original room dimension specifications (or the modifications taking workload into consideration as shown in Table 1) are highly desirable for purposes of both operation and protection.

If the minimum requirements specified in the table are met, and if the workloads are typical of those found in most rural hospitals (e.g., less than 10 milliampere-minutes per week) it is quite probable that no additional shielding, besides that provided by the room walls, will be required.

**Radiation Protection Experience**

Radiation protection surveys have been conducted at the aforementioned test sites in Chile, Colombia, and the United States in collaboration with personnel of local radiation protection services pertaining to the ministries of health in Colombia and Chile and the Mount Sinai Medical Center in the United States (13). The results of these surveys, which were made on the WHO BRS-type X-ray machines manufactured by the General Electric, Philips, and Siemens companies, can be summarized as follows:

1. The total permanent filtration of the useful X-ray beam met or surpassed the requirements of the International Commission on Radiological Protection (ICRP) (14).
2. The useful X-ray beam was precisely aligned with the X-ray film. Tests performed with a beam alignment test tool demonstrated that the beam-centering was within two degrees of strict coincidence.
3. The collimator limited the useful beam to the area of the film. In all cases the difference between the X-ray field and the film was within the generally accepted limits of 2% of the source-to-image distance.
4. The movable patient pointer easily enabled the operator to ensure that the area of clinical interest was in the center of the X-ray beam.
5. The lead shielding in the back of the cassette holder performed satisfactorily as an X-ray beam shield, attenuating approximately 99.6% of the primary beam at 120 kV.
The amount of radiation scattered to the operator's position in front of the protective shield was very small, and it was not possible to detect radiation behind the protective shield.

The reproducibility of the radiation output during repeated exposures at various selected kilovolt and milliampere values was excellent.

With regard to patient exposure, the radiation dose that a patient might receive during the most common X-ray examinations (chest, abdomen, lumbo-sacral spine, and skull) was estimated utilizing a methodology developed by the U.S. Center for Devices and Radiological Health. The results for the WHO BRS-type X-ray machines manufactured by General Electric, Philips, and Siemens that were used in clinical field trials in Latin America were then compared with average values obtained in the United States and with ranges of values reported by the ICRP (15). With only one exception (this being the chest radiographs at one test site) the patient's radiation exposure from the WHO BRS-type machines was less than the average patient exposure values found in the United States, where a concerted effort has been made over the past two decades to reduce the patient's radiation exposure.

Significantly higher patient exposure values were obtained on a sample basis from various conventional X-ray departments throughout Latin America that were not using WHO BRS-type equipment. In one instance (without control for differences in the film, intensifying screens, and processing) the patient exposures from the four common examinations mentioned previously were found to be 250% to 700% higher than patient exposures from a WHO BRS-type unit installed nearby. In each of the two X-ray departments involved, the same consultant radiologist examined the radiographs and judged them to be of satisfactory diagnostic quality.

Conclusions

The Basic Radiological System developed by PAHO and WHO, within the context of extending coverage to underserved populations, makes use of high-quality components. These (including the tube, generator, focused grid, tube stand, and patient examination table) have been combined in an optimum design configuration that is deceptively simple. As a result of a profound analysis of the X-ray examination process (an analysis that preceded issuance of the WHO specifications), it has become possible for a health worker with a minimum amount of training to consistently produce high-quality radiographs.

Due partly to elimination of all electrical components except the X-ray tube and generator, the BRS X-ray machine is rugged, easy to install, and easy to maintain.
Protection of the patient and X-ray operator have been incorporated into the design. Results obtained in field trials have shown that much less radiation exposure is received by the patient when the BRS machine is used than when similar examinations are performed with conventional X-ray machines.

The WHO Basic Radiological System employs the most appropriate available technology for producing a high-quality radiograph at reasonable cost in small hospitals and in health centers serving marginal urban areas. In larger referral and university hospitals, the BRS can perform about 80% to 95% of the X-ray examinations required, thus liberating scarce resources to purchase and install more complex equipment where it is truly needed.

References


2. Hanson, G. Estrategia y métodos para lograr el acceso universal a unos servicios radiológicos de alta calidad en América Latina. Paper presented at the VII Spanish Radiology Seminar cosponsored by the Mt. Sinai Medical Center, Miami Beach, and the Inter-American College of Radiology (Miami, Florida, 7–13 April 1985).


WHO Supports Intrauterine Devices

A WHO scientific group convened to look into the modes of action, safety, and efficacy of intrauterine devices (IUDs) recently concluded that they are "probably the most effective and reliable reversible method of fertility regulation available to women."

The group emphasized that it was referring to the currently available copper- and hormone-releasing IUDs, when properly used.

The experts also noted the particular situation in the United States, where two manufacturers discontinued making and marketing IUDs in response to increasing legal costs arising from lawsuits in which pelvic infection and subsequent infertility were claimed to have resulted from IUD use. In their report, the experts stated that the decisions to withdraw the Lippes Loop, Copper-7, and TCu-200 IUDs from the American market "were based on commercial and financial considerations rather than on questions of safety."

In general they considered the IUD to be "an important method of fertility regulation with high continuation rates and significant advantages in convenience of use." But they also stressed the need to carefully screen women considering using IUDs to ensure that no contraindications such as genital cancers, vaginal bleeding of unknown cause, suspected pregnancy, or active pelvic infection were overlooked. The text of the group's report has been published in WHO Technical Report 753, which is available from the World Health Organization, 1211 Geneva 27, Switzerland.