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Research Paper

RADIATION PROTECTION IN DESIGN OF PET-CT FACILITY TO REDUCE DOSES FOR OCCUPATIONAL PERSONNEL AND PATIENTS

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PET-CT facility is gaining paramount importance, in molecular imaging for Nuclear Medicine (NM) and tomography. The importance of this modality is due to the fact that it provides valuable clinical information. It becomes essential for the user to know about the design regulatory requirement, and radiation safety precautions. That one has to take for the installation of this new modality in their premises. The various stages of approval of PET-CT facility, and important steps that follow before planning for this facility are summarized in this paper. Staff and patient flows in the Unit are critical to ensure that, patients staff, and visitors are not exposed to radiation, as a result of traffic circulation through or adjacent to areas occupied by dosed patients and scanning rooms. Effective layout can also reduce the need for costly radiation shielding.

Keywords: Radiation protection, PET-CT facility, Nuclear medicine, Tomography

INTRODUCTION

Plans and specifications will require assessment for radiation protection by a certified expert; the radiation protection assessment will specify the type, location and amount of radiation protection required according to the final equipment selection and layout. Radiation protection requirements shall be incorporated into the final specifications and the building plans. Radiation shielding will be required to a number of areas.

Radiation protection aspects of PET-CT facilities, NM facility with PET-CT, can result in a shielding requirement. Even modest reductions in the radiation levels at 511 keV require significant amounts of shielding.

Unit design and operational Policies should address the management of radioactive substances. The Room should be located near the entry to the Nuclear Medicine Unit to ensure patients do not unnecessarily cross areas of radioactivity. The Bone Densitometry room should be located away from dosed patients by distance or shielding to avoid interference to the Bone Density Unit from high ambient radiation levels. it that important there location A ground floor site is preferred but if this cannot be achieved,

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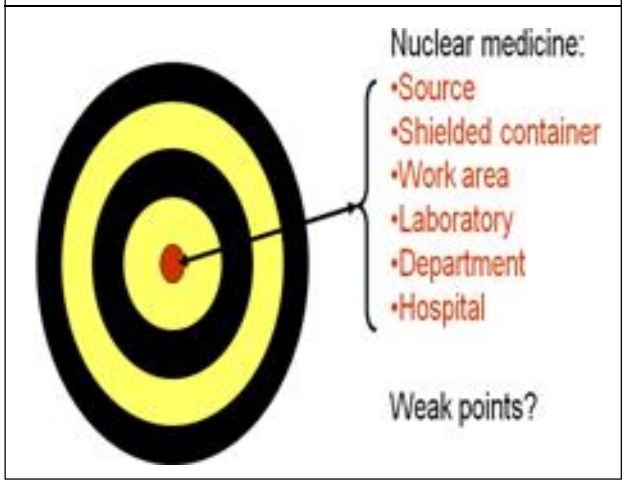
consideration should be given to units above, below and adjoining the proposed location with regard to radiation shielding requirements, the weight of equipment and associated shielding and access for equipment and radioactive isotopes. The Unit should not act as a thoroughfare to other units of the healthcare facility.

Radiation protection aspects of PET-CT facilities, Nuclear Medicine facility with PET-CT employs relatively large activities of high-energy photon emitting radioisotopes. This coupled with the current dose limits for members of the public, can result in a shielding requirement. Even modest reductions in the radiation levels require significant amounts of shielding. A thorough and site-specific evaluation has to be made for each facility.

A ground floor site is preferred but if this cannot be achieved, consideration should be given to units above, below and adjoining the proposed location with regard to radiation shielding requirements, the weight of equipment and associated shielding and access for equipment and radioactive isotopes. The Unit should not act as a thoroughfare to other units of the healthcare facility. Waiting areas should allow separation of does and undoes patients; some patients may need to wait for 45 minutes after dosing for uptake. It is also preferable to separate dosed patients from relatives. Dosed patients should have access to drinking water and toilet facilities without having to access general waiting areas.

Figure 1: Explain Process Shielding Requirement



Safety design Equipment, additional to the Defense in Depth. Requires should take into consideration the type of work and the radionuclide and their activities intended to be used. The concept of 'categorization of hazard' should be used in order to determine the special needs concerning ventilation, plumbing, materials used in walls, floors and work benches, Signs, labels and records, Shielding, Floors, Impervious material, and Curved to the walls Glued to the floor No carpet.

METHODOLOGY

Single Photon Emission Computed Tomography (SPECT)

PET-CT shielding requirements are being used for design to shielding is a follows:

Obtain an architectural layout of the facility having dimensions of each of the rooms associated with the facility. Determine the expected workload (number of patients per week) of the facility, maximum radioactivity to be administered per procedure, and CT workload, total mass and kV/p per patient. Determine the occupancy of areas within the facility and in adjacent, uncontrolled areas. Include consideration of occupancies at floors above and below the facility. Determine the location of the place where all the initial activities of radioisotopes are to be dispensed. This also includes the injected patient working area.

The Designer has to clearly indicate the dimension of each of the rooms associated with the facility in the proposed layout plan of the NM department. When the user has to plan the laboratory, it is required that the arrangement of the various rooms associated with the facility has to follow the principle of low active area to high active area, that is, entrance of the facility should have reception/general waiting area, and at the end hot laboratory cum radiopharmacy radioactive waste storage area is to be planned. The typical layout plans for the facility given in Figure 1 may be referred to design the PET-CT facility alone or PET-CT facility along with the gamma camera facility with respect to the arrangement/allocation of rooms.

Radiation Protection

Plans and specifications will require assessment will specify the type, location and amount of radiation protection required according to the final equipment selections and layout. Radiation protection requirements shall be incorporated into the final specifications and the building plans. Radiation shielding will be required to a number of areas as including:

- Reception and rooms adjacent to dosed patient rooms
- Dosing/Consult Exam rooms
- Hot Lab/Dispensing room/Radiopharmacy
- Pre-scan uptake rooms/dosed waiting areas, patient toilets
- Cardiac Stress Testing Room
- Scanning Room/s
- Post scanning waiting areas
- Bone Densitometry Room

Location

A ground floor site is preferred but if this cannot be achieved, consideration should be given to units above, below and adjoining the proposed location with regard to radiation shielding requirements, the weight of equipment and associated shielding and access for equipment and radioactive isotopes. The Unit should not act as a thoroughfare to other units of the healthcare facility.

Unit Layout

Staff and patient flows in the Unit are critical to ensure that patients, staff and visitors are not exposed to radiation as a result of travel through or adjacent to areas occupied by dosed patients and scanning rooms. Effective layout can also reduce the need for costly radiation shielding. Layout should address the need for separation of areas particularly patient and staff corridors and entry areas for outpatients and inpatient on beds/trolleys. Unit design and operational Policies should address the management of radioactive substances including how radioactive substances will be delivered to the Unit and how radioactive waste will be removed. If provided, the Bone Density Room should be located near the entry to the Nuclear Medicine Unit to ensure patients do not unnecessarily cross areas of radioactivity. The Bone Densitometry room should be located away from dosed patients by distance or shielding to avoid interference to the Bone Density Unit from high ambient radiation levels.

Patient Waiting

Waiting areas should allow separation of dosed and undosed patients, particularly as some patients may need to wait for 45 minutes after dosing for uptake. It is also preferable to separate dosed patients from relatives and

visitors to the unit which may include young adults, pregnant women and children. Dosed patients should have access to drinking water and toilet facilities without having to access general waiting areas. Outpatients should be separated from inpatients for privacy reasons with separate entrances.

Planning Model of Care

The model of care will depend on level of services provided as defined in the service plan and the presence or otherwise of PET as a sub-component of the Nuclear Medicine Unit. In large centres, it will be a discrete unit. If there are only one or two gamma cameras, it may be a discrete sub-unit of Medical Imaging. All units will have a Hot Laboratory (Hot Lab). Large centres may or may not include a Radiopharmacy Laboratory that will prepare its own radiopharmaceuticals for general use.

Functional Areas

The Nuclear Medicine Unit consists of the following functional areas:

- Reception/Administration
- Waiting areas for outpatients and inpatients, including toilets
- Patient holding, observation and recovery area
- Treatment areas including gamma camera rooms, specialised scanning imaging rooms (SPECT, PET, PET/CT, bone densitometry), stress testing facilities
- Support areas including utilities, staff station
- Hot Lab/Radioactive Waste Store
- Staff areas including offices and amenities
- Teaching and research facilities (Tertiary Centres)

Design Construction Standards

- Flooring shall be adequate to meet load requirements for, patients, and personnel.
- Floors and walls should be constructed of materials that are easily decontaminated.
- Walls should contain necessary support systems for either built- in or mobile oxygen and vents for radioactive gases.
- Ceiling height should be a minimum of 3 meters in procedure or scanning rooms.

Natural light is desirable in all patient areas. Lighting level in reporting rooms needs to be adjustable. Safety and Security floor finishes and junctions should be smooth, impervious and non-absorbent in case of radiation spills. Building Service Requirements. Ceiling spaces above gamma cameras and specialty scanning units should not be used for hydraulic services or air-conditioning ducts, to avoid damage to equipment from leakages. The need for delayed holding tanks within the Nuclear Medicine Unit will require assessment by the Radiation Consultant.

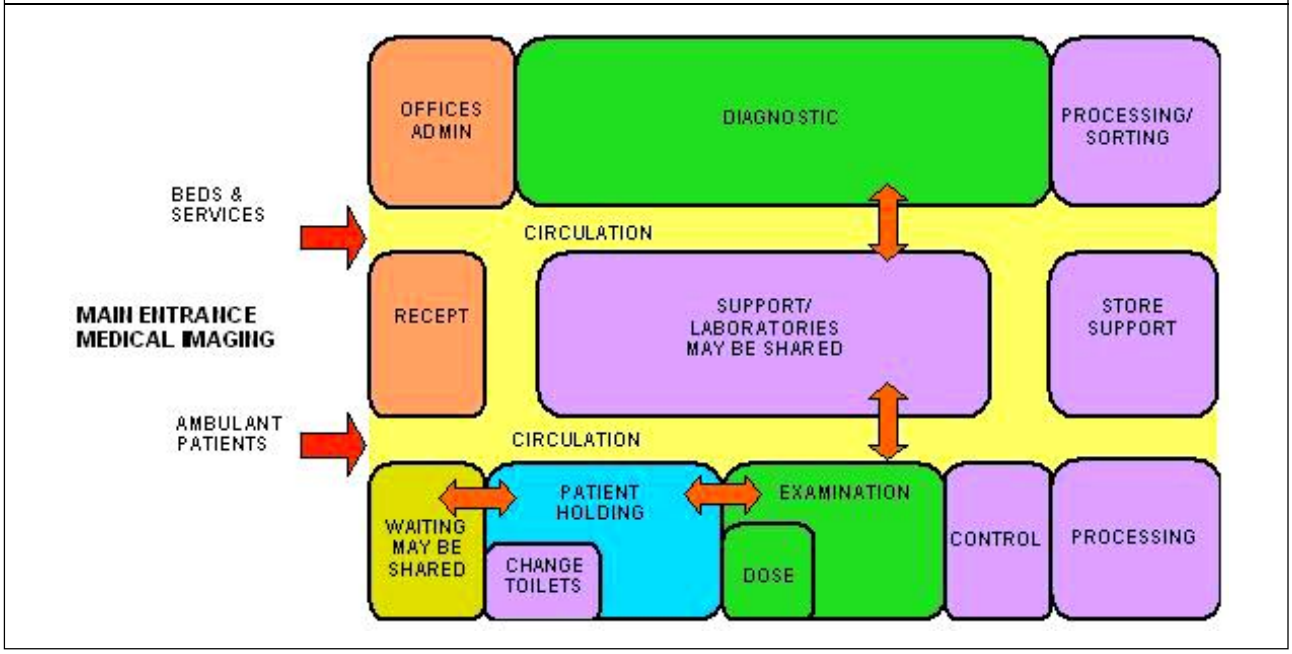
Location and Relationships

Scanning rooms require ready access from dosing rooms and dosed patient waiting areas. Scanning rooms may be collocated with shared Control rooms to enable monitoring of two rooms simultaneously. On the basis of the previous study, we begin to design distribution module for nuclear medicine unit. To achieve optimal of access to reduce the exposure of workers to excessive doses.

Nuclear Medicine Unit Functional Relationship Diagram

The Nuclear Medicine Unit should be located with ready access to the Medical Imaging Unit, PET Unit if provided, Emergency Unit, Operating Unit

Figure 2: Explain Functional Relationship Modular



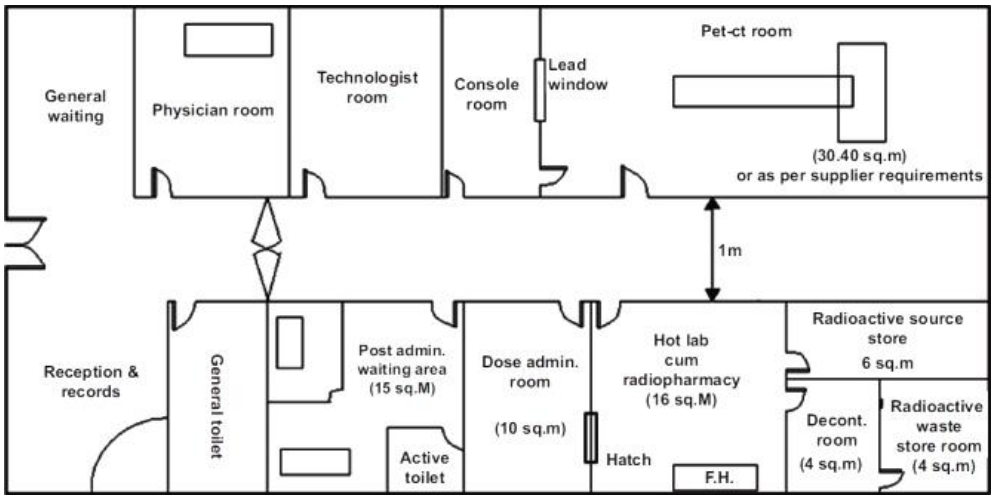
and Critical Care areas. It requires easy access for ambulant patients and beds/stretchers.

OPERATING SUGGESTION

Transporting and positioning the patient are the operations that deliver, significant exposure to the technologist. Maximize separation from the patient after injection and minimize the time spent with them. Patient instruction should be completed before injection, allow as much separation as feasible when they are escorted to the scanner room. Minimize the time spent near the patient in the scanner room.

A typical layout of a positron emission tomography-computed tomography (PET-CT)

Figure 3: The Typical Layout Plans for the Facility



facility. Note: All the walls of the PET-CT facility should be made of thick brick or thick concrete but the walls of PET-CT room should be concrete only, the thickness of which depends on the area and workload.

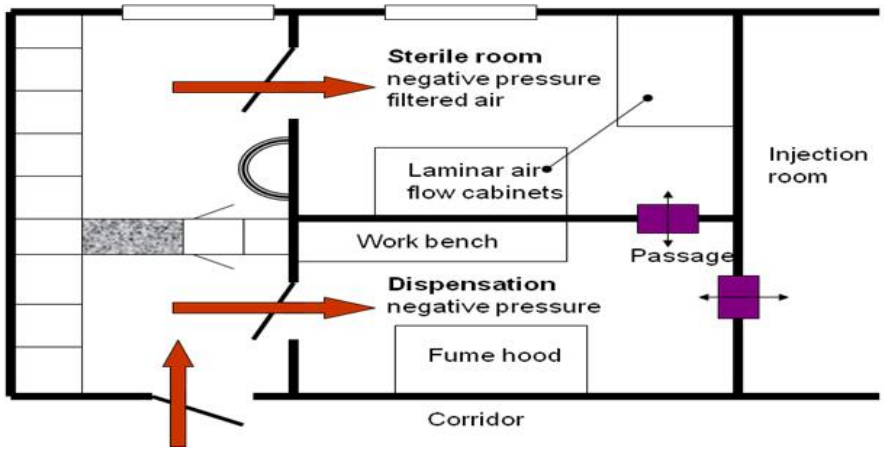
Ventilation

Additional cooling and ventilation will be required to Scanning Rooms and associated computer equipment rooms as the equipment is sensitive to excessive ambient heat. Some scanners may require chilled water for cooling. Large temperature changes (greater than 40 °C per hour) within scanning rooms need to be avoided to reduce the risk of crystal fracture in

gamma cameras. Additional air extraction or exhaust may be required to Camera Room/s where ventilation agents such as the gas are administered. In the restricted areas of Patient Examination Room and Storage and Preparation areas, if radioactive gas Xenon is being used, special ventilation is required. Ventilation requirements would be in accordance with the Nuclear Regulatory Commission, publication "Guide for preparation of Application for Medical Use Program" Guide 10.8, Appendix 0, edition August 1987 – revision 2. The restricted area should be kept under negative pressure by exhausting at least 15 % more air than supply air. Recirculation of air from these spaces should not be permitted.

Laboratories in which unsealed sources, especially radioactive aerosols or gases, may be produced or handled should have an appropriate ventilation system that includes a fume hood. The ventilation system should be designed negative pressure relative to surrounding areas. The airflow should be from areas of minimal likelihood of airborne contamination to areas where such contamination is likely (Figure 4). All air from the laboratory should be vented through a fume hood and must not be recirculated either directly, in combination with incoming fresh air in a mixing system, or indirectly, as a result of proximity of the exhaust to a fresh air intake.

Figure 4: The Airflow Should be from Areas of Minimal Likelihood of Airborne Contamination to Areas Where Such Contamination is Likely



Note: *Part 4. Design of Facilities- Safety of Sources- Module 4.2. Work with Sources

*IAEA Training Material on Radiation Protection in Nuclear Medicine Part 4. Safety of Sources Design of facilities- Module 4.4. Defense in Depth

The fume hood must be constructed of smooth, impervious, washable and chemical-resistant material. The working surface should have a slightly raised lip to contain any spills and must be strong enough to bear the weight of any lead shielding that may be required. The air-handling capacity of the fume hood should be such that the linear face velocity is between 0.5 and 1.0 metres/second with the sash in the normal working position. This should be checked regularly.

Sinks

The release of aqueous waste to the sewer a special sink shall be used. for the discharge shall be available. The sink shall be easy to decontaminate. Special flushing units are available for diluting the waste and minimizing contamination of the sink. The wash-up sink should be located in a low-traffic area adjacent to the work area. Taps should be operable without direct hand contact and disposable towels. should be access to an emergency shower in or near the laboratory.

In the case of Patient Toilet. A separate toilet room for the exclusive use of injected patients is recommended.

A sign requesting patients to flush the toilet well, to ensure adequate dilution of excreted radioactive materials and minimise contamination.

The facilities shall include a wash-up sink, Washrooms designated for use by nuclear medicine patients should be finished in materials that are easily decontaminated. The patient washing facilities should not be used by hospital staff.

NATURAL LIGHT

Natural light is desirable in all patient areas, staff room and staff offices. Lighting level in reporting rooms needs to be adjustable. External windows provided in scanning and uptake rooms should be assessed by a Radiation Consultant for shielding requirements.

Safety and Security

The Nuclear Medicine Unit shall include a safety shower with an eyewash station for use in the event of radioactive spills.

Finishes

Floor finishes and junctions should be smooth, impervious and non-absorbent in case of radiation spills. Nuclear Medicine Unit Generic Schedule of Accommodation.

Table 1: Accommodation for a Nuclear Medicine Unit for Level 4-6 Entry / Reception Area

ROOM/ SPACE	Standard Component			Level4 Qty x m2	Level 5 Qty x m2	Level 6 Qty x m2	Remarks
RECEPTION	RECL-10-U RECL-15-U			1 x 10	1 x 10	1 x 15	
WAITING – MALE/FEMALE	WAIT-10-U WAIT-20-U			2 x 10	2 x 15	2 x 20	Separate Male/female areas
MEETING ROOM – SMALL	MEET-9-U MEET-12-U			1 x 9	1 x 9	1 x 12	
OFFICE – SHARED	OFF-2P-U OFF-3P-U			1 x 12	1 x 12	1 x 15	2/ 3 staff
STORE – PHOTOCOPY/STATIONERY	STPS-8-U STPS-10-U			1 x 8	1 x 8	1 x 10	
STORE - FILES	STFS-8-U STFS-10-U			1 x 8	1 x 8	1 x 10	

Table 1 (Cont.)

ROOM/ SPACE	Standard Component			Level 4 Qty x m2	Level 5 Qty x m2	Level 6 Qty x m2	Remarks
WAITING – UNDOSED (MALE/FEMALE)	WAIT-SUB-U WAIT-10-U			2 x 5	2 x 5	2 x 5	Separate Male/female areas
PLAY AREA – PAEDIATRIC	PLAP-10-U			1 x 10 optional	1 x 10	1 x 10	
PATIENT BAY – HOLDING (MALE/FEMALE)	PBTR-H-10-U			2 x 10	3 x 10	8 x 10	Separate Male/female areas
BAY - BEVERAGE	BBEV-OP-U			1 x 4	1 x 4	1 x 4	
BAY – HANDWASHING	BHWS-B-U			1 x 1	1 x 1	2 x 1	
BAY – LINEN	BLIN-U			1 x 2	1 x 2	2 x 2	
BAY – RESUSCITATION TROLLEY	BRES-U			1 x 1.5	1 x 1.5	1 x 1.5	
CLEANER'S ROOM	CLRM-5-U			1 x 5	1 x 5	1 x 5	
CONSULT ROOM	CONS-U			1 x 14	2 x 14	4 x 14	Qty dependent on Service Plan
DIRTY UTILITY – SUB	DTUR-S-U DTUR-10-U			1 x 8	1 x 8	1 x 10	
DISPOSAL ROOM	DISP-5-U DISP-8-U			1 x 5	1 x 8	1 x 10	May be shared at Level 4
STAFF STATION/ CLEAN UTILITY	SSCU -U			1 x 9	1 x 9	1 x 9	
STORE – STERILE STOCK	STSS-12-U			1 x 6	1 x 12	1 x 12	
TOILET - ACCESSIBLE PATENT	WCAC-U			2 x 6	2 x 6	4 x 6	
SHOWER – PATIENT MALE/FEMALE	SHPT-U			2 x 4	2 x 4	4 x 4	
CIRCULATION ALLOWANCE %				35%	35%	35%	

Table 2: Patient and Support Areas Treatment Areas

ROOM/ SPACE	Standard Component			Level 4 Qty x m2	Level 5 Qty x m2	Level 6 Qty x m2	Remarks
GAMMA CAMERA ROOMS (WITH INTERNAL CONTROL)	GCAM-U			1 x 38	1 x 38	1 x 38	
SPECT SCANNING ROOM (WITH CONTROL ROOM)	GCAM-U similar				1 x 42	2 x 42	Size to suit equipment
SPECT/C.T SCANNING ROOM					1 x 48	1 x 48	
SPECT/C.T SCANNING CONTROL ROOM	ANCRT-U similar				1 x 14	1 x 14	
COMPUTER EQUIPMENT ROOM	COEQ-U			1 x 8	3 x 8	4 x 8	
STRESS TESTING	STRT-U			1 x 12	1 x 12	2 x 12	
BONE DENSITOMETRY					1 x 16	1 x 16	
BAY – MOBILE EQUIPMENT	BMEQ-6-U			1 x 6	2 x 6	4 x 6	Qty according to equipment to be accommodated
PROCEDURE ROOM	PROC-20-U					1 x 20	Optional
VIEWING/REPORTING ROOM	XRRR-U			1 x 12	1 x 12	1 x 12	
CIRCULATION ALLOWANCE %				35%	35%	35%	

Note: *IAEA Training Material on Radiation Protection in Nuclear Medicine - Part 4
*Part 4. Design of Facilities Safety of Sources- Module 4.1. Sources

RESULTS

The Nuclear Medicine Unit should be located with ready access to the Medical Imaging Unit, PET Unit if provided, Emergency Unit, Operating Unit and Critical Care areas. It requires easy access for ambulant patients and beds/ stretchers.

CONCLUSION

PET-CT facilities involve somewhat different design requirements than conventional NM facilities and are more likely to require additional shielding. By providing good handling facilities and following good work practices, radiation dose to the staff, public, and environment can be maintained well below the acceptable limit. To reduce exposure to operating personnel in the PET-CT facility and to improve instrument performance. Requires The should take into consideration the type of work and the radionuclides and their activities intended to be used. The concept of 'categorization of hazard' should be used in order to determine the special needs concerning ventilation, plumbing, materials used in walls, floors and work benches, Signs, labels and records, Shielding, Floors, Impervious material, and Curved to the walls Glued to the floor No carpet!

Walls and Ceiling Should be finished in a smooth and washable surface with joints being sealed, wherever practicable. Walls should be painted with washable, non-porous paint (e.g., gloss paint). As such should be taken into account waiting room Worktop Surfaces must be finished in a smooth, washable and chemical-resistant surface with all joints sealed. Some laminates do not resist certain chemicals, and the supplier Open shelving should be kept to a minimum to prevent dust accumulation. Services (e.g., gas, electricity, vacuum) should not be mounted on top of the bench, but on walls. Light fixtures should be easy to clean and of an enclosed type in order to minimize dust accumulation. Structural reinforcement may be necessary, since a considerable weight of lead shielding may be placed on counter tops.

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