Models, Parameters and Technical Options for Controlling Internal Contamination and Reducing Radiation Doses of Exposed Workers in a Radioiodine Treatment Department

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Introduction

In the following we describe the characteristics of our Department building, work organization and the main choices and solutions assumed to assure radiation protection for workers in our Radioiodine Treatment Department. Also we compare our Department with other Italian Treatment Departments, analyzing the most interesting data from each one. The relationship between Radiation Protection performance and choices made before and after our Department opening will be discussed.

Department description

S. Maria Nuova Hospital in Reggio Emilia is a typical town Hospital (about 900 beds). Radioiodine Department data are shown in the first line of Table 1. This is a medium sized Department (four treatment beds) which was opened in the December 1997. A Radioprotection program with modern criteria and technology was adopted during both the planning and working stages.

The Department is located on the ground floor at the South-East wing (Figure 1) inside a modern building including Nuclear Medicine (first floor) and Radiotherapy (ground floor).

Figure 1. Department building

The plan of the Department is reported in Figure 2. The perimeters of the Controlled areas (where the workers' dose absorbed in one year could be more than 1mSv) are drawn in red, while the perimeters of the supervised areas (where the workers' dose absorbed in one year could be more than 6mSv) are drawn in yellow [2]. In the following we describe the plan of the Department, mentioning the main characteristics of each room:

The patients must use the patients corridor to reach the main waiting room, where they are checked before admittance to the Department;

A cold dressing room (civilian clothes) and a hot dressing room (work clothes) compose the dressing room; only workers use this area;

The decontamination room contains „hands-feet and clothes monitor", „decontamination shower" and „washbasin". „Hands-feet and clothes monitor" must be used by workers before going out to the patients' corridor. The shower and washbasin can be used only for decontamination operations, because they are connected to the „Liquid Stocking System". This system (located in front of the building in Fig.1) collects radioactive organic liquid disposals from patients in treatment. In the decontamination room a wardrobe is used to change work clothes and shoes and a shielded tank is used to collect contaminated clothes.

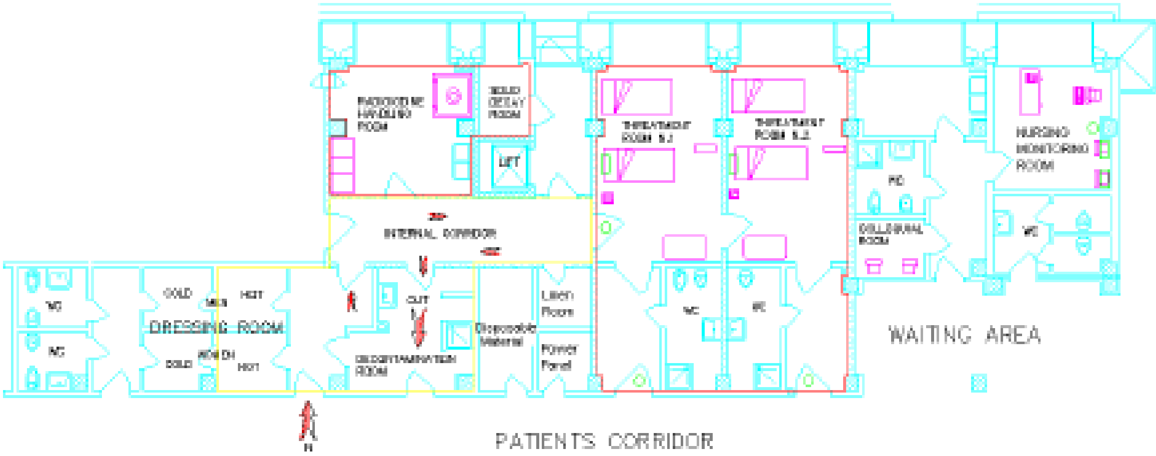


Figure 2. Department plan.

The lift is used both by Physician and Nursing personnel for passing between the Radioiodine Treatment Department (ground floor) and the Nuclear Medicine Department (first floor); the lift can also be used by the Physics personnel for passing between the Radioiodine Treatment Department (ground floor) and the Liquid Stocking System (underground floor);

The radioiodine handling room is used for handling and administrating radioiodine doses to the patients. Radioiodine is handled inside a shielded glove box where a forced ventilation system with carbon active filters operates. The shielded glove box also contains: a dose calibrator; a safe for temporary stocking of radioiodine doses; some tanks for collecting contaminated disposal materials.

In the radioiodine handling room there is a shielded safe, composed of six shelves, useful for stacking high, medium and low contaminated materials; before stocking in the shielded safe, organic contaminated materials are collected in 25 liter poliethylen cans.

The solid decay room stores material used in the treatment rooms. The two treatment rooms are provided with separate bathrooms (connected to the Liquid Stocking System), TV cameras and intercoms (to watch and talk to the patient from both the nursing monitoring station and the colloquial room). In the nursing monitoring station there is also an electrometer display connected with an ionization chamber on the patient's bed. The chamber is useful for measuring the patient's radiation dose rate during the treatment. In addition we have one G.M. probe on each one of the three entrance doors facing the treatment rooms; G.M probes are connected to a control display in the nursing monitoring station too.

Remote controls in the nursing monitoring station allow personnel on duty to check the patient in treatment.
The internal corridor is used during daily work. It becomes the main waiting room for patient and personnel during general fire or earthquake alarms: it is a safety area provided with forced ventilation and fire shielding doors.

The service rooms contain non-contaminated linen, disposable material and the power distribution room.

In the entire treatment area, the walls have a Baritic Concrete shield (17 cm thick); ceiling shielding is provided by Baritic Concrete (60 cm thick) with the addition of 3-mm of lead. This very important shielding was sized using Monte Carlo Method. It is necessary to protect the Nuclear Medicine Gamma Cameras located just over this room. Doors are provided with 3-mm of lead shielding.

Floors and walls are covered with linoleum (up to 2 meters high) that allows easy cleaning during decontamination operations.

Department organization

Workers paths description

(Nurses)

- At the first daily entrance Nurses go into the (men or women) dressing room. First they leave their civilian clothes in the cold side and after put on their working clothes in the hot side; they wear some single use accessories such as gloves, overshoes and overclothes. They can't go into the Internal Corridor if they aren't completely dressed.

- They mustn't stay in the treatment room more than the necessary time to successfully finish their job.

- At the end of the operation, they go out threw the internal corridor and stop in the decontamination room;

- In decontamination room they must remove the single use accessories, check for eventual residual contamination on their hands, shoes and clothes with the monitor (proceeding with decontamination if it is necessary).

- They must note in a designated form their final residual contamination, entrance and exit time and date and the kind of operations made.

- They exit directly into the patients' corridor.

- The next daily entrances in Classified areas must be done without passing threw the dressing room; they go directly into the entrance room.

(Physicians)

- They enter Nuclear Medicine Department (first floor) and go down by lift to the internal corridor (ground floor).

- They go into the radioiodine handling room from the internal corridor.

- Physicians must remain in the radioiodine handling room, close to the shielding glove box, in order to handle and administer doses. At the end of the operations, Physicians go out threw the internal corridor and stop in the decontamination room;

- In decontamination room they must remove the single use accessories, check for eventual residual contamination on their hands, shoes and clothes with the monitor (proceeding with decontamination if it is necessary).

- They must note in a designated form their final residual contamination, entrance and exit time and date and the kind of operations made.

- They exit directly into the patients' corridor.

(Physics personnel)

- They can follow either the Nurse or Physician paths; moreover, if it is necessary, Physics personnel can use the lift to get to the Liquid Stocking System or into the M.C.A. room (each one on the underground floor).

(Relatives and other workers)

- They must follow the Nurse path.

Lenght of hospital stay – Italian survey

Stay patients with Thyroid Carcinoma are cured with high doses of I-131 in about 30 Radioiodine Treatment Departments in Italy. These Centers were contacted and asked to complete a survey, containing information about the mean activity administered to patients, the average lengths of hospital stay and dose rate threshold for patient discharge.

General results are presented in Table 1.

Table 1: Survey results

	Patients/year			Average		Days stay in Hosp		
Italian Regions	**CA Ablation**	**Methastasis.**	**Beds number**	**CA Ablation**	**Methastasis.**	**CA Ablation**	**CA Methastasis**	**Threshold in μSv/h*m**
Emilia	35	65	4	65	115	4	4	25
Emilia	114	70	4	80	150	3	5	10
Veneto	230	120	4	120	200	5	5	10
Veneto			2	200	200	3	3	100
Lombardia	40	90	3	50	200	4	4	50
Lombardia	170	80	6	100	150	4	4	17
Lombardia	18	5	2	30	200	4	4	4
Lombardia	163	167	14	100	200	8	9	5
Friuli	60	40	3	80	130	4	4	10
Toscana	180	120	8	80	120	3	3	50
Toscana	500	300	2	80	250	3	3	50
Toscana	60	40	2	96	166	2	4	40
Lazio	82	103	3	100	180	3	4	15
Campania	35	150	4	30	100	2	3	30
Sicilia	133	32	2	70	150	2	3	20
Lombardia	50	30	2	110	200	4	5	10

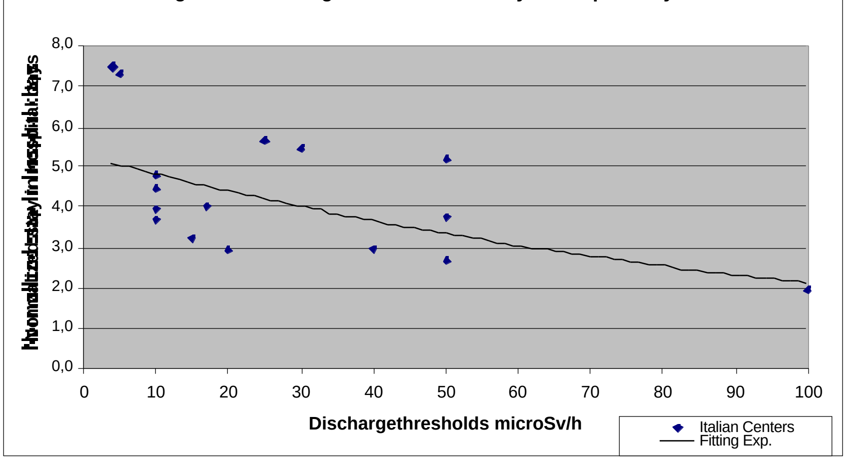
An analysis of the dose rate value thresholds indicated an average value of about 28 microSv/h at 1 meter. It's not so far from 25microSv/h at 1 meter or 400MBq in residual activity, which is the value for discharge suggested by the European Commission in its last Draft [1].

If we look at the survey results, we can see how the chosen thresholds for patient discharge can influence both clinical and logistic choices. The dose administered to patients is strictly correlated to the stay in hospital. Department opening days during the week determine the number of workers necessary to assure patient care.

Figure 3 shows the distribution of the dose rate discharge level versus the normalized average patient stay. The average length of stay in hospital was obtained by averaging the two kinds of pathology (methastasis and ablation). Normalization is obtained by multiplying the lenght of stay in hospital by the ratio of the average dose administered in that Department and the average dose administered in all Italian Departments investigated.

As represented in Graph 1, this parameter shows an exponential decreasing trend.

Figure 3: Discharge thresholds vs stay in hospital days



Most of the Centers (more than 80%) adopt a threshold value between 10 to 50 microSv/h at 1 meter.

An intermediate value of dose rate seems preferable for the following reasons:

- Lower dose rate values would increase the length of stay in hospital (from 4, to 6 or 7 days) with a significant increase inlogistic costs (isotope administration is generally done on Monday so that the patient stay is protracted during the week end).
- Higher dose rate values would increase the dose burden to the population who live around the Department, and the number of hospital days could not decrease by more than one.

Day stay in hospital - Our choice

We decided to open the Department five days a week, from Monday to Friday, with the following number and kinds of workers:

- Four Nurses to assure constant assistance to patients during the day;
- Two Part –Time Cleaner workers to assure Treatment room cleaning during critical days (patient discharges);
- Physicians and Physics personnel are always available;

Looking at the Italian situation before (Figure 3), with an intermediate stay in hospital of 3 to 5 days, the exponential trend suggests an intermediate discharge threshold according to our discharge threshold of 25 mSv/h at 1 meter. Our discharge threshold shows a stay of one day less in hospital; analysis of the patients' dosimetry data treated in our Department in the last two years gives the same result.

We have seen that reducing from five days to four the average stay in hospital and planning workers timetables for a the week, we can treat fifty more patients in a year, without adding any costs.

Workers education and training

In a Radioiodine Treatment Department, where Radiation sources are not equipment but patients in treatment, technology safety doesn't assure Radioprotection. We have to improve radioprotection threw personnel education and training; correct workers' behaviour is obtained respecting both Internal Radioprotection Regulations and Work Procedures.

Internal Radioprotection Regulations establish rules that each group of workers of the same profession (Nurses, Physicians, Physicists, etc) has to respect during his routine job . Work Procedures are necessary when a job is shared among different professionals. There is a work procedure for each shared operation which assures a good execution of the shared job in agreement with Radioprotection.
In a Radioiodine Treatment Department Radioprotection depends on a good workers' training and education of Radioprotection Regulations and Work Procedures observation.

Italian law [2] imposes radioprotection education and training for all workers who use radiation sources. In Radioiodine Treatment Department we repeat education and training courses every year . During educational courses (organized as in Figure 4) we study Internal Radioprotection Regulations while during training courses we practice Work Procedures.

Figure 4. Courses planning.

Work rules

A critical situation where different kinds of professionals are working together, normally needs a work procedure. To realize a good work procedure it is necessary to have good integration among different professionals. Each professional worker has to carry out his contribution for the procedure at a good level and at the same time collaborate with other involved workers. Let's look at one of our procedure:

Discharge patient procedure:

- Physicist, who has to decide the discharge patient threw dose rate measured at 1 meter; moreover, during patient exit, he has to avoid any kind of contamination outside the treatment rooms.

- Physician, who has inform the patient about what he must do during the next two weeks.

- Nurse with the responsibility of patient comfort to the end of discharge.

- Cleaner personnel who have to clean the treatment room before patient exit to avoid the patient bringing contamination outside.

The procedures are periodically updated. In Table 2 a list of the procedures is shown.

Table 2: List of most the critical procedures in force

Subject	***Purpose***	***Involved workers***
Contamination monitoring in to the Classified areas	To perform standards work formality. To assure radioprotection of the patient, worker and population. To avoid contamination outside of the Classified areas.	MPD personnel. Cleaner personnel.
Modalità operative per una corretta dimissione dei pazienti ricoverati nella Sezione di Terapia Metabolica	To perform standard work formality.To assure radioprotection of the patient, worker and population.To respect dismission treshold in force.	MPD personnel. Cleaner personnel.Nursing. Physician.
Dose administration to the patient	To assure radioprotection of the patient, worker and population	MPD personnel. Physician.
Solid disposals management.	To perform standard work formality.To assure radioprotection of the patient, worker and population.To respect limits in force about activity concentration .	MPD personnel. Cleaner personnel.

Periodical Department Meeting

A Department meeting is a chance to improve both organization and procedures. Every four months the Radioiodine Treatment Department personnel have a meeting to talk about Department organization and new work procedures. Each meeting is official recorded. Until now during Department meetings improvement in procedures and in staff performance have been obtained.

Physics surveillance

Medical Physics Department (MPD) personnel is available during normal daily work and is on duty during the night, assuring a 24 hours physics surveillance during Radioiodine Treatment Department opening.

Equipment

Radioprotection is conditioned by the equipment chosen. In Tables 3 and 4 the equipment which has been selected and its use is shown.

Table 4: Equipments to assure radioprotection of the population

Equipment	***Purpose***
Forced ventilation system with active carbon filter	To protect population by reducing air contamination in the outside environment .
Liquid Stocking System. It is composed by three 15 mc tanks to stock liquids from treatment rooms for an average period of 60 days. Only after a sample measuring by M.C.A. well, external discharged is allowed.	To protect population by reducing water contamination in the outside environment
Portable M.C.A. spectrometer	It is employed in solid disposals management.
Portable probe to measure floor contamination	To avoid any kind of contamination outside treatment rooms, checking the goodness of the floor cleaning during dismission of the patient.

Table 3: Equipments to assure radioprotection of patient and worker

Equipment	***Purpose***
A TV camera and intercom in each treatment room	To check the patient from Nursing Guard room or Colloquial room
A G.M. probe over each entrance door to the treatment rooms	to alert personnel in Nursing Guard room with automatic alarm, in case of forbidden exit of the patient
Bed with two pair of 3-cm of lead shields	To protect patient, worker and visitor from external irradiation.
A 3-cm of lead personnel's portable shield	To protect worker and visitor by external irradiation from not walking patient.
Every kind of single use accessories as gloves, overshoes and overclothes, mask with carbon active filter. Emergency/decontamination material located in decontamination room.Hands-feet and clothes monitor.	To protect worker and visitor by contamination and internal irradiationduring permanence in Classified areas.
A portable M.C.A.spectrometer. A fixed M.C.A. spectrometer in a 6-cm lead well located in M.C.A. room, close to Stocking System.	To realize internal dosimetry monitoring on the worker and on solid and liquid disposals..
Ionization Chambers located over the patient's bed with remote control to display from Nursing Guardroom.	To realize internal dosimetry monitoring on the patient during the treatment.

Organization

Physics surveillance in the Radioiodine Treatment Department is assured by correct MPD personnel behaviour; in Table 5 the routine job timetable for MPD personnel is shown; job planning has allowed us to reach the following results:

1. Uniform behaviour inside MPD personnel group.
2. Job distributions, day by day during the week, in order to complete each routine.
3. Job distribution depends on the day of the week; for example doses administered to the patients on Monday or patients' discharge on Friday.
4. Monthly calendar of MPD personnel on duty with each one's telephone number is shown in the Nursing monitoring station; it's available for emergency MPD personnel call by the Nurse, in case of contamination or Liquid Stocking System alarms.

Table 5: Routine MPD personnel's jobs on Monday

08,00 AM	08,30 AM	09,00 AM	09,30 AM	10,30 AM	11,30 AM	03,30 PM	04,00 PM
Information by orders register from MPD worker who is getting out of duty to MPD worker who is getting on duty;	Presence in Handling room during dose administration, dose measure by dose calibrator	From Nursing Guardroom: Patient dosimetry by Ionization Chamber (I.C.) located over patient's beds, recording data on Files.xls. Update treshold of 3 G.M. probe.	Monitoring on solid disposal and eventual stocking with Cleaner personnel helping	To check the PC management software of the Stocking System.Imhoff dose rate measure with HP 1010 inside the Stocking System.	Collection of worker's urine sample and worker's thyroid detection monitoring	Contamination monitoring inside Classified areas to informe Cleaner personnel on hot areas before daily cleaning.	Patient dosime from Nursing Guardroom b Ionization Cham (I.C.) located o patient's bed

Documents

Documents normally used by MPD personnel during continuous surveillance are:.

1. <u>MPD personnel orders register</u> used to assure continuity of the MPD worker going off duty and the MPD worker coming on duty; a record of events is recorded which is important for Radioprotection investigations;

2. Format documents to record and collect information about Radioprotection; format documents are simply a print of Excel (Microsoft) data sheets used to record written data.

The most important format documents used daily to record data are:

- patient dosimetry data measured by Ionization Chamber located over the patient's bed;
- worker internal dosimetry data measured in urine collected and by thyroid detection;
- entrances / exits and time of permanence in the classified areas; also on this form the final residual contamination, direct readable on the portable dosimeter worn by the worker, kind of operations made in classified areas are noted;
- dose rate measures made on the patient during his stay in hospital (each 8 hours) and before his discharge.

Training

Training normally concerns:

1. Education and training courses. Whenever MPD personnel need training on a new procedure or instrumentation, the Physicist plans a course;

2. Periodical meetings to improve organization and procedures; reference document about MPD procedures is „MPD personnel memorandum“ in which can be found:

   - procedures to follow during routine weekly jobs;
   - procedures to follow during accident or emergency cases;

Patient dosimetry

Patient dosimetry is obtained by an initial and some periodical (every 8 hours) dose rate measures by Ionization Chamber (I.C.) located over the patient's bed in the Treatment room. Measures are assured by MPD personnel on duty, using remote control instruments installed in the Nursing Monitoring station (an overview is shown in Figure 5); each patient's measure is performed with a known distance between I.C. and patient. In this way measure repeatability is assured. Dosimetry data analysis permits the drawing of the patient's residual activity exponential and the calculation of the residence time [3]

Worker dosimetry

External irradiation dosimetry is measured by portable TLD dosimeters; workers wear a total body dosimeter during a period of 45 days and a hand dosimeter during a period of 90 days .

Internal irradiation dosimetry is controlled every month by collecting a worker's urine sample; the activity of radioiodine in urine excretion is measured by employing a scintillation gamma spectrometer with a crystal of NaI (tl) 3“ diameter in a 6-cm lead shielded well.

Worker's thyroid detection monitoring is obtained by employing a portable scintillation gamma spectrometer (MCA) with a crystal of NaI(tl) 3“ diameter; each worker is investigated every fifteen days in routine monitoring and every day for a week in special monitoring (in case of accident) in order to respect ICRP 54 and 78.

To obtain residual activity, we compare the urine residual activity with the thyroid residual activities both measured at the same time. To evaluate worker's dose it would be necessary to know exactly intake instants. To calculate with maximum precision the intake instants, we read the entrances/exits form document compiled by the worker at the classified areas exit; for each worker's entrance in classified area we obtain a factor of intake probability, directly proportional to:

- total activity, adding the activity in the patients to the activity of the sources, present in classified areas at the entrance;
- how long the permanence is in classified area ;
- kind of job made in classified area, with relative risk of inalation, contamination and ingestion.

Environmental dosimetry

Every four months there is an environmental dosimetry survey around classified areas; the results obtained are recorded and used for the next evaluations.

Patients discharge procedure

Remote measures by ionization chambers located over the patient's bed in the treatment room, let the Physicist know the effective decay time (Te) of the patient's residual activity and at the same time when the patient's dose rate is reaching discharge threshold.

Before patient discharge, the Physicist measures dose rate at 1 meter from the patient using a proportional chamber; to dismiss the patient, it must be measured with good accuracy and repeatability not more than 25 mSv/h at 1 meter. [1]

The Physician gives orders to the discharged patient to carry out in the next two weeks.

Accidents and Emergency

Liquid Stocking System - the most frequent alarm

During the last year in the Department about ten alarms were recorded, generally connected with incorrect functioning of the remote signal from either Full / Too Full floatings or Pumps. One third of the alarms occurred during the night and needed MPD personnel presence.

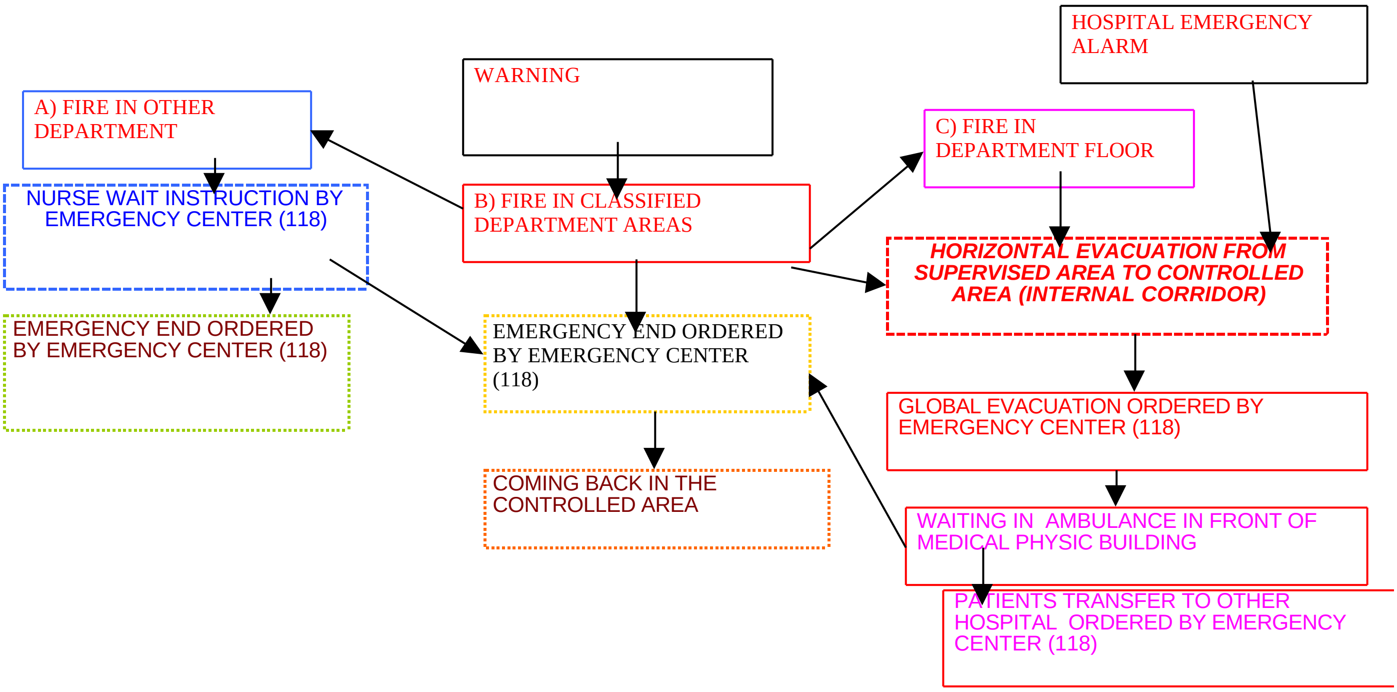
Patient's vomiting and incontinence

During the last year in the Department patient's vomiting and incontinence happened only twice, but only one of these caused significant environmental contamination; in that case the alarm began the following actions by MPD personnel:

- Environmental decontamination in cooperation with Cleaner personnel and Nurse.
- Immediate calculation of patient's residual activity, useful for Physician.
- Thyroid special monitoring for the involved workers (ICRP 54)
- Written relation, including brief history about what happened, decontaminations made and involved workers'dose evaluation.

Emergency - Internal emergency plan

A Radioiodine Treatment Department Emergency Plan was made by collaboration between MPD Personnel and Hospital Prevention and Protection Department; the latter has responsibility to make a Hospital Emergency Plan. In the following Flow Chart the actions planned in case of fire or earthquake emergency are shown. MPD personnel have been qualified by the Fireman Department to assist during a Fire Emergency.



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Physics surveillance: *Workers* Dosimetry