RADIODIAGNOSTIC EQUIPMENT: REGULATIONS AND MATERIOVIGILANCE

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Summary: The use of medical devices (MDs) in the field of medical imaging has always been governed by rigorous regulations, in particular the authorizations and compliance of radiological installations and premises in view of the risks generated by the ionizing radiation produced by these MDs. The regulatory bases that deal with equipment emitting ionizing radiation are diversified between those specific to the protection of the public and users of ionizing radiation and those relating to medical devices. In addition, radio-diagnostic equipment must provide all the guarantees in terms of the balance between benefits and risks. Although radiation protection is essential, materiovigilance is one of the key elements of technological monitoring and surveillance of the risks that may result from the use of these medical devices after they have been placed on the market. The Moroccan legislation has a legal arsenal in accordance with the model of the World Health Organization's global regulatory framework for medical devices. It outlines regulations and adheres to international guidelines in the field of vigilance against ionizing radiation. However, it is necessary to move on to the specification of procedures in order to remove any ambiguity .

Key words: Medical device, Ionizing radiation, Radio-diagnostic equipment, Materiovigilance, Regulations

1 Introduction

Regulation of the use of medical devices (MDs) in medical imaging is necessary because of the high cumulative risks of ionizing radiation that have a significant impact on health [1]. One of the key elements of technology watch is the limitation of these risks to the lowest possible level in addition to their monitoring [2].

The regulation of radiological diagnostic equipment must be complete and rigorous, from the classification of the MD to the quality management system, in order to clear up any confusion in design, manufacture and use. In fact, the legal arsenal is a fundamental pillar for guaranteeing the materiovigilance of this equipment and clarifying the procedure for reporting incidents and accidents caused by ionizing radiation in a context of health vigilance.

The short-term side effects of ionizing radiation are related to high doses, and are well known and rare. However, the problem arises for low doses where the risk only appears after a long period of time due to the accumulation of doses [3-4]. As a result, vigilance regarding exposure to ionizing radiation is particularly delicate. The aim of this study is to analyze the regulatory basis of radiological equipment and to highlight the materiovigilance of diagnostic radiological equipment and its role in improving the health of persons exposed to ionizing radiation in order to better rationalize the management of risks associated with care.

2 Method of work

List of the different diagnostic radiological equipments:

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- Inclusion criteria: having an X-ray tube for diagnostic purposes;
- Exclusion criteria: a radioactive source and / or therapeutic purpose

Compare the different regulatory aspects of diagnostic radiological equipment, namely

- Law 84-12 of Morocco,
- The orders n° 2853.2854.2855.2856 relating to medical devices
- Regulation 2017/745,
- Directive 93/42 EEC and
- The World Health Organization (WHO) Global Regulatory Framework for Medical Devices model

As well as those related to radiation protection, particularly Law 142-12, implementing decrees 2-97-30 and 2-97-132 and Directive 2013/59 Euratom;

To carry out a bibliographic study to explore and study the materiovigilance of radiological diagnostic equipment and the associated risks on the databases: "Scopus", "web of science", and Pubmed" during the period 2010-2021.

To highlight the materiovigilance of these equipments and the information concerning the incidents and accidents occurred because of the ionizing radiation through the following key words of research: materiovigilance, vigilance, radiology, effects of the ionizing radiation.

3 Results

Diagnostic X-ray equipment, the subject of this study, includes all the MDs that meet the inclusion and exclusion criteria, which operating principle is based on the emission of an X-ray beam, its attenuation after transmission from an anatomical region and its projection onto a radiological film for diagnostic purposes[5]. Several categories of this equipment are designed to adapt to specific needs in medical imaging, we note :

- Standard / conventional bone-lung X-ray machine
- Mobile radiology apparatus
- Remotely controlled fluoroscopic radiography apparatus
- Mammograph
- Surgical C-arm brightness enhancer
- Scanner
- Osteodensitometer
- Dental Panorama
- Retroviolent radiography apparatus

3.1 regulatory framework

3.1.1 classification

Identifying which class of MD an X-ray tube belongs to is the first step in determining the regulations in force, specifically the conformity of the equipment. For that, we use the nomenclature "Devices emitting ionizing radiation intended for radiodiagnosis" to explore the classification of radiodiagnostic equipment in the regulatory texts.

For the regulation of MDs in Morocco, the approved classification proposes an estimate of the risk level [6] in accordance with the World Health Organization (WHO) global regulatory framework model for medical devices [7]. This reference gives examples of each category where X-ray emitting MDs are found in class "C" with a medium-high risk level.

Table 1. Classification of diagnostic X-ray equipment according to the different regulatory texts

Regulation	Class	
	Source of radiation	Image Processing
Act 84-12	Is not indicated	
Directives 93/ 42EE	Class IIb	IIa
Regulation 17/745	Class IIb	IIa
WHO Terms of Reference 2018	Class C: medium-high risk	Not mentioned

Law 84-12 only mentions the four classes of medical devices (I; IIa; IIb; III), and as far as the classification rules are concerned, they are determined by the order of the Minister of Health n° 2856-15. The latter postulates that radiodiagnostic devices belong to class IIb MD [8].

According to rules 9, 10, 11 and 17 of Annex VIII of Regulation 2017/745 that deal with the classification of MD, it is concluded that the X-ray tube is qualified as "*active device for diagnosis, provides information and allows the detection, diagnosis, control (...) of physiological conditions, health conditions, diseases or congenital malformations*"[9] and it was clearly stated that it is part of class IIb. In addition, devices that control, monitor and act on the performance of the tube (control panel, generator, table, anti-diffusion grid, etc.) are also in the same class. On the other hand, devices specifically intended for recording diagnostic images generated by X-ray irradiation are in class IIa. This classification is the same as in the 93/42 EEC directives.

Despite the changes made to the classification criteria, at the level of Regulation 2017/745, there were no changes to MDs emitting ionizing radiation.

3.1.2 Manufacturing and conformity assessment requirements

The second chapter of Annex I of Regulation 2017/745 is entirely dedicated to radiation protection and takes up the same texts of Directive 93/42 EEC concerning the design and manufacture of tubes to reduce the exposure of all persons in contact with radiation (user, patient and public) while controlling the quantity and quality of radiation emitted by an adequate adjustment [9, 10] and brings back additional expressions insisting more on three points: First, the need to take into consideration the Directive 2013/59 Euratom [2] laying down the basic standards for health protection against hazards arising from exposure to ionizing radiation. Secondly, it is necessary to choose the methods and means that allow the reduction of exposure especially to intentional (scattered) radiation from the design and manufacture. Thirdly, to have, as far as possible, monitoring of the amount and geometry of radiation during exposure.

And if the directive 93/42 EEC stipulates that the instructions for use of said MD must describe the information necessary to reduce the risk emanating from radiation by specifying its nature, the type of risk and the means of protection. The regulation 2017/745 adds that it is necessary to communicate also on the instructions for use, the acceptance and performance tests, the maintenance approach, in addition to the malfunctions or variations in performance that may influence safety.

As for conformity assessment for all class IIb devices, clinical investigations must be performed and documented under the normal conditions of use of the MD. This implies post-marketing surveillance to keep the clinical data up to date [9].

Concerning the Moroccan regulation, Article 19 of Law 84/12 is the only one that deals with medical devices emitting ionizing radiation and refers to the legislation relating to protection against radiation, in particular Annex II of Order 2856-15, which deals with the quality, safety and performance requirements for MD. The latter includes the requirements of Directive 93/42 EEC in its entirety. There is also Law 42-12, which outlines the general principles [11] of radiation protection. And while waiting for the application decrees to specify the technical characteristics, decrees n° 2-97-30 and 2-97-132 are still applicable. These decrees require the same international design and manufacturing performance, and demand CE marking or approval in the country of construction, without necessarily having a specific procedure for conformity assessment [12-13].

3.1.3 MD registration

The registration of a MD requires a declaration of the economic operator and his contact details, information about the device (type, risk class, etc.)[6, 8, 9] .

Regulation 2017/745 registration requires first having a unique identifier (IUD-id base) in addition to the registration or unique identification number of clinical investigations, [9], then registration in the EUDAMED database [14].

In Morocco, the registration certificate (Article 15 of Law 84/12) requires prior clinical investigation and evaluation of clinical data [6]. As for the decree 2855, it requires the ISO 13485 certificate or equivalent, declaration of conformity to the quality, safety and performance requirements and the draft labeling and instructions for use [8].

3.1.4 Quality Management System

Having a quality management system (QMS) is an obligation in a vision of reducing the risks inherent in the use of ionizing radiation and increasing the accuracy of diagnosis. The reference support is the regulation 2017/745 which highlights a well-detailed quality management system and all the life stages of a MD, whether during manufacturing, marketing or even after commissioning, in order to guarantee the performance of the equipment. This regulation describes the procedure to be followed and the necessary documentation. However, directive 93/42 EEC insists on the QMS without specifying the procedure.

For law 84-12, it only requires the maintenance of equipment and the continuous evaluation of clinical data without mentioning a QMS for medical devices, while law 142-12 on nuclear and radiological safety, given the specific nature of radiological equipment, stipulates that the operator must implement a quality assurance program and obliges users to ensure maintenance and quality control both internal and external.

3.2 Materiovigilance

Materiovigilance must be integrated into the field of ionizing radiation use via the regulatory requirements that are the pillars of risk management and prevention in health care institutions. It is generally based on the notification of serious incidents inherent in the use of medical devices.

During the life cycle of radiological equipment, materiovigilance begins at the design stage and even at the manufacturing stage of the radiation source and the enclosure that protects it. It continues after the equipment is put into service via a complete information system for reporting incidents and accidents related to the use of the equipment. Moreover, the prevention of any malfunction and the prediction of corrective actions is a primordial step for the safety of a MD.

All regulatory texts require clinical investigations and evaluations in order to guarantee the safety and quality of the services provided by MD. The purpose of these clinical investigations is to ensure the performance of the device under normal conditions of use, and to specify any adverse effects that may occur following its

use, thus enabling a conclusion to be reached on the risk-benefit ratio of the device

Table 2. Key elements of material safety according to the different regulatory authorities

	Act 84-12	Directives 93/ 42EE	Regulation 2017/745	WHO Terms of Reference 2018
Compliance	Issued by an organization in the country of manufacture Technical document: evaluation of clinical data or clinical investigation	Notified body: Risk Analysis Clinical evaluation	Notified body: Clinical evaluation Benefits/risks based on clinical data	Regulatory authority of the country of manufacture or importing country. Clinical evidence of compliance with performance and quality requirements
Incident Reporting	Reporting of serious incidents within 48h to the registrant	Obligation to notify	Notified any incident and corrective action within 15 days	Must appear in the primary legislation of a country
Clinical investigation	The registrant shall note the comments within 15	Under the responsibility of the manufacturer Investigation Protocol Ethics Committee	Clear investigation procedure by notified body	According to ISO 14155/ 2011 standards
Traceability	Written report	Written report	EUDAMED database	No information

Regulation 2017/745 emphasized vigilance by first requiring the manufacturer to conduct a clinical evaluation of MDs before they are placed on the market, and prescribed a process for reporting adverse reactions and corrective actions under QMS by further involving the manufacturer in post-market surveillance of MDs.

The importance of the vigilance granted by the regulation is clearly visible when it has integrated clinical investigations, incident reports, MD defects and applied safety measures into the electronic system of the European MD database. Furthermore, these data will be taken into account during the inspections of the notified bodies and can even be used for a reclassification of the MD.

While the regulation places more emphasis on materiovigilance, Decree 2-97-30 places more importance on the installations and conditions of use of radiological equipment by making MD operators responsible for the protection of users and the public. It also requires a system for recording the results of individual dosimetric monitoring of workers exposed to ionizing radiation.

Within the framework of vigilance in the field of ionizing radiation, Regulation 2017/745, Decree 2-97-30 and Directive 2013/59 Euratom, postulate the presence of a sound or visual signaling system during the emission of radiation with the aim of limiting the access of people to the radiation areas thus ensuring their protection.

At present, in addition to periodic inspections of radiological facilities, clinical investigations are carried out following individual dosimetric monitoring of users of ionizing radiation in case of exceeding the dose threshold specified in the international radiation protection regulations [2-12], in order to detect problems and anticipate the occurrence of a serious incident.

Clinical data on the effects of radiation show that professionals working with ionizing radiation before the Second World War showed secondary effects such as leukemia and cancers of the skin and lung [15], but research after this period is insufficient to show the relationship between the dose and the effects observed [15-16]. Similarly to patients, it is difficult to associate the development of long-term cancers with radiological exposure [17].

4 Discussion

X-ray tube technology has been in use for a long time, and its serious risks are well described as well as the performance requirements of the equipment available on the market. However, the Moroccan legal framework is a work in progress and still needs to be developed.

By referring to the model of the WHO's global regulatory framework for medical devices, Moroccan regulations cover the basic legal basis and the risks involved in their use, as set out in this reference.

Moreover, it complies with international good practices, particularly in radiation protection and handling of ionizing radiation sources. Nevertheless, there are more general decrees, awaiting application decrees for technical specifications that have not yet been decreed, as well as for labeling and instructions for use, for which the regulations do not specify the elements that must be included, which may cause non-homogeneity on the market.

Regarding the conformity of imported equipment, Morocco adopts a system of recognition of the regulatory decision of other bodies in the importing country. In addition, it has national regulatory bodies that monitor compliance and materiovigilance during the registration of MD in general (National Consultative Commission for Medical Devices) [6] and those emitting ionizing radiation in particular (Moroccan Agency for Nuclear and Radiological Safety) [11].

Compared to Directives 93/42 EEC, Regulation 2017/745, adds new conditions for the compliance of MD and the requirement of clinical data for its marketing. As it has well emphasized the materiovigilance by requiring the manufacturer to have a quality management system and involving it more in the post-marketing surveillance and especially in the process of reporting serious incidents.

The new requirements of the European regulation in relation to the quality and risk management of MD refer respectively to the ISO 13485 and ISO 14971 standards. In general, these standards take up a large part of the regulation, whose compliance with these requirements will facilitate obtaining certification and conversely, a certified company will have a cohesion with the requirements of the regulation [18,19,20].

In addition, the regulation emphasized clinical investigations as a requirement for clinical evaluation in a continuous process throughout the life cycle of the medical device.

Traceability and post-marketing follow-up have their place in materiovigilance and are closely linked to clinical investigations. This will be ensured in the first place through the Unique Identifier System on MD (IUD) which will improve the traceability of MD and fight against counterfeiting. secondly, the EUDAMED database, which includes all the information needed to identify MDs, their performance, their investigations and the corrective actions taken in case of failure [14]. These systems will facilitate a comprehensive and simplified analysis of safety data. They will also allow an optimization of the traceability, since all the data are grouped and computerized.

In medical imaging, radiation accidents are more frequent when handling radioactive sources [21-22] than when using x-ray sources in radiodiagnostics [3-15]. The low radiation doses immanent to X-ray tubes cause long-term effects and for which regulations require rigorous safety standards for radiological facilities and practices in order to reduce to the lowest possible level the exposure of professionals and patients as well as the public [2, 3, 11].

In this sense, the actions carried out in terms of materiovigilance have a preventive character, and current efforts are focused on the Diagnostic Reference Levels (DRL) and the corresponding Diagnostic Guide Value (DGV), which set the accepted dose for each radiological examination in parallel with the calibration of the radiation sources [2]. In fact, calibration consists of "the measurement or adjustment of an instrument, a component or a system to ensure that its accuracy or response is acceptable" [11]. For radiological equipment, this operation is intended to guarantee the quality and intensity of ionizing radiation, and must be carried out by approved technical organizations [8-11].

Recent epidemiological studies, after the introduction of radiation protection regulations and the technical requirements of radiological facilities, do not sufficiently exploit the risk of low doses generated by the use of ionizing radiation in radiodiagnostics [17-23].

In the perspective of vigilance in the field of low-dose ionizing radiation, particularly used in radiodiagnostics, epidemiological studies on a large sample and for a long period of time are recommended in order to identify the various risks related to low-dose radiological exposure in professionals and patients.

5 Conclusion

The comparative study concerning equipment emitting ionizing radiation has highlighted the contribution of the new European regulation 2017/745 for the Law 84/12 in the field of medical devices, particularly clinical investigations and materiovigilance.

Indeed, radiodiagnostic equipment must meet some requirements regarding clinical evaluation, post-market surveillance and technical documentation. All this to ensure the quality, safety and performance of the said devices. The European Regulation 2017/745 has further involved manufacturers in vigilance throughout the life of the medical device, and consequently engaged them in a continuous process of safety improvement in cooperation with other vigilance bodies and organizations.

With respect to the regulation of medical devices in Morocco, the technical specifics need to be detailed in the implementing legislation for greater precision. In addition, national regulatory authorities need to be involved in moving from basic to more advanced regulatory measures in line with the recommendations of the WHO Model Regulatory Framework for Medical Devices.

Finally, the focal point of the materiovigilance implemented via the regulatory texts is the patient who will also be positively impacted by the new requirements. These requirements are intended to ensure patient safety and to anticipate any serious accident related to the use of medical devices. In such a context, we advocate a technical teaching in materiovigilance at the level of the different training cycles for all users of ionizing radiation.

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