IMPLEMENTATION OF THE 2015 GUIDELINES ON THE STANDARDIZATION OF PROTOCOLS IN RADIOLOGICAL DIAGNOSTICS IN THE ASL BT

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ABSTRACT

Drafting of standardized protocols referring to standard patients according to the 2015 National Guidelines, each of which will be associated with a dose index ("dose class"), pursuant to Legislative Decree 101/2020, article 161, paragraph No. 6.
study, data were collected from the execution on at least 5 patients of the practices admitted to standardization, for each hospital belonging to the ASL BT, using a CR detector and the values of the set parameters were recorded (kV, mA, exposure time, fi e-bed distance, focus-detector distance, field size, SEV, use or not of the AEC, possible use of the anti-diffusion grid). For each protocol, the associated effective dose was then calculated and the corresponding dose class assigned.
Starting from the analysis of the data, 33 standard protocols were proposed for the execution of bone densitometric radiographic examinations, with a single densitometric model, and traditional radiology with two different OPT equipment and a remote-controlled model, installed in the ASL BT facilities.
The study represents the proposal of 33 standard protocols for the execution of radiological examinations on the examined equipment, for each of which the associated dose class has been verified, which agrees with the reference one. Starting from the protocols obtained, it has been shown that the use of AEC involves a dose saving for the patient. In the ASL BT it is therefore possible to proceed with the implementation of the Guidelines.

Abbreviations
AEC (Automatic Exposure Control) – AP (anteroposterior) –PA (postero-anterior) - LL (lateral-lateral) – AX (axial) – OBL (oblique) – SIRM-SNR (Italian Society of Medical and Interventional Radiology - National Union of Radiological Area) – DAP (Dose Area Product)

INTRODUCTION

The National Guidelines of reference for Diagnostic Imaging, cited by Legislative Decree 101/2020 in Title XIII "MEDICAL EXPOSURES", provide an exhaustive list of traditional radiological practices admitted to standardization, each of which is associated with its own National Code provided for by the SIRM-SNR Radiological Performance Nomenclator, with the aim of applying the basic principles of radiation protection (justification and optimization of the procedure).
This Decree provides that each Region aligns itself with the National Guidelines and that the Direction and Health of each public or private health company, where radiological services are carried out, adopts them and implements them.
The purpose of the study is the drafting of a standard protocol for each of the aforementioned practices to be implemented in all the offices of the ASL BT and that, once entered into force, the TSRM can carry out autonomously, without the need for the presence of the Radiologist in the radiological room. Each type of examination performed with a standardized protocol will be associated with a "dose class", an effective dose range designed to estimate the radiation dose received by a standard patient undergoing the procedure.

MATERIALS AND METHODS

Data collection took place only in 4 presidia of the ASL BT.
In each of the locations, diagnostic tests scheduled daily, as routine, were performed, paying particular attention to those that are considered suitable for standardization by the National Guidelines and for which the National Code of the Nomenclator (updated in 2017) and the Regional Code (Tab. 1) are specified.
Patients for whom at least one of the aforementioned diagnostic tests was requested were:
inquire about how to conduct the exam;
prepared, inviting them to sign the informed consent, if necessary, to remove all metal objects in the region of interest;
instructed to maintain a fixed position during the ex-

CLAVICLE X-RAY	AP	58	100	22	0,22	YES	100	80	24	30	YES		I
	AX	70	100	20	0,2	NO	100	80	24	30	YES		
SCAPULA X-RAY	AP	64	100	30	0,3	NO	100	80	24	30	YES		I
	OBL	70	100	29	0,29	NO	100	75	24	30	YES		
HUMERUS X-RAY	AP	68	100	15	0,15	YES	100	85	35	43	YES		I
	LL	75	100	15	0,15	YES	100	85	35	43	YES		
ELBOW X-RAY	AP	53	100	9	0,09	NO	100	90	24	30	NO		I
	LL	53	100	9	0,09	NO	100	90	24	30	NO		
FOREARM X-RAY	AP	58	100	9	0,09	NO	100	90	35	43	NO		I
	LL	58	100	10	0,1	NO	100	90	35	43	NO		
WRIST X-RAY	PA	51	100	6	0,06	NO	100	95	18	24	NO		I
	LL	51	100	6	0,06	NO	100	92	18	24	NO		
HAND X-RAY	PA	50	100	5	0,05	NO	100	97	18	24	NO		I
	OBL	50	100	5	0,05	NO	100	95	18	24	NO		
PELVIS X-RAY	AP	83	100	37	0,37	NO	115	85	35	43	YES	0,65	I
HIP JOINT X-RAY	AP	82	100	42	0,42	YES	100	70	24	30	YES	0,9	I
	AX	82	100	42	0,42	YES	100	70	24	30	YES		
SACROILIAC JOINT X-RAY	AP	81	100	49	0,49	NO	110	80	24	30	YES	0,86	I
	OBL	81	100	49	0,49	NO	110	70	24	30	YES		
FEMORAL X-RAY	AP	72	100	36	0,36	NO	105	85	35	43	YES		I
	LL	71	100	36	0,36	NO	105	85	35	43	YES		
KNEE X-RAY	AP	66	100	17	0,17	NO	100	85	24	30	YES		I
	LL	66	100	17	0,17	NO	100	85	24	30	YES		
PATELLA X-RAY	AX	45	100	8	0,08	NO	100	85	18	24	NO		I
LEG X-RAY	AP	59	100	16	0,16	NO	100	85	35	43	NO		I
	LL	59	100	16	0,16	NO	100	85	35	43	NO		
ANKLE X-RAY	AP	54	100	9	0,09	NO	100	90	24	30	NO		I
	LL	54	100	9	0,09	NO	100	90	24	30	NO		
FOOT X-RAY	PA	51	100	9	0,09	NO	100	90	24	30	NO		I
	LL	53	100	9	0,09	NO	100	90	24	30	NO		
	OBL	53	100	9	0,09	NO	100	90	24	30	NO		
HEEL X-RAY	LL	49	100	10	0,1	NO	100	90	18	24	NO		I
	AX	51	100	11	0,11	NO	100	90	18	24	NO		
LUMBAR DENSITOMETRY	AP	105	125	2,5	50	YES			20,4	11,4		0,0005	I
FEMORAL DESITOMETRY	AP	105	125	2,5	50	YES			20,4	11,4		0,0005	I

Fig. 1 - *ANNEX I: STANDARDISED PROTOCOLS*
**Note: Due to the lack of data recorded with AEC, for some standardized radiological practices it was not possible to rpropose a protocol with AEC, replaced for this reason by the protocol without AEC.*

PRACTICE N°	GUIDELINES 2015	NATIONAL CODE 2017	NUMERIC REGION CODE	DESCRIPTION	PROJECTION TYPE (AP/LAT/ OBL)
1	87.11.3	87.11.3	15401	ORTHOOVERVIEW OF DENTAL ARCHES (OPT)	
2	87.12.1	87.12.1	15541	TELERADIOGRAPHY OF THE SKULL. For orthodontic cephalo-metry	PA
					LL
3	87.17.1	87.17.4	16101	SKULL AND PA-RANASAL SI-NUES X-RAY (three projections)	PA
					LL
					PA PAR. SIN.
4	87.16.1		15833	NASAL BONES X-RAY	LL
					AX
5	87.16.1	87.16.7	15829	RIGHT HEMIMAN-DIBLE X-RAY	OBL
6	87.16.1	87.16.7	15830	LEFT HEMIMANDI-BLE X-RAY	OBL
7	87.22	87.22	16311	CERVICAL SPINE X-RAY (2 projections)	AP
					LL
8	87.23	87.23	16381	THORACIC SPINE X-RAY (2 projections)	AP
					LL

9	87.24	87.24	16451	LUMBOSACRAL SPINE X-RAY (2 projections)	AP
					LL
10	87.44.1	87.44.1	17431	CHEST X-RAY (2 projections)	PA
					LL
11	87.43.2	87.43.3	17361	RIGHT HEMICOSTAT X-RAY	AP
					OBL
12	87.43.2	87.43.3	17363	LEFT HEMICOSTAT X-RAY	AP
					OBL
13	87.43.2	87.43.4	17365	STERNUM X-RAY	OBL
					LL
14	87.43.2	87.43.5	17367	RIGHT CLAVICLE X-RAY	AP
					AX
15	87.43.2	87.43.5	17369	LEFT CLAVICLE X-RAY	AP
					AX
16	88.21	88.21.2	50523	RIGHT SHOULDER X-RAY	AP INTRA
					AP EXTRA
17	88.21	88.21.2	50525	LEFT SHOULTER X-RAY	AP INTRA
					AP EXTRA
18	88.21		20519	RIGHT SCAPULA X-RAY	AP
					OBL
19	88.21		20521	LEFT SCAPULA X-RAY	AP
					OBL
20	88.21	88.21.3	20515	RIGHT HUMERUS X-RAY	AP
					LL
21	88.21	88.21.3	20517	LEFT HUMERUS X-RAY	AP
					LL
22	88.22	88.22.1	20585	RIGHT ELBOW X-RAY	AP
					LL
23	88.22	88.22.1	20587	LEFT ELBOW X-RAY	AP
					LL
24	88.22	88.22.2	20589	RIGHT FOREARM X-RAY	AP
					LL
25	88.22	88.22.2	20591	LEFT FOREARM X-RAY	AP
					LL
26	88.23	88.23.1	20663	RIGHT WRIST X-RAY	PA
					LL
27	88.23	88.23.1	20665	LEFT WRIST X-RAY	PA
					LL
28	88.23	88.23.2	20659	RIGHT HAND X-RAY	PA
					OBL
29	88.23	88.23.2	20661	LEFT HAND X-RAY	PA
					OBL
30	88.26	88.26.1	20793	PELVIS X-RAY	AP
31	88.26	88.26.2	20795	RIGHT HIP JOINT X-RAY	AP
					AX
32	88.26	88.26.2	20797	LEFT HIP JOINT X-RAY	AP
					AX

33	88.26	88.26.1	20799	RIGHT SACROILIAC JOINT X-RAY	AP
					OBL
34	88.26	88.26.1	20801	LEFT SACROILIAC JOINT X-RAY	AP
					OBL
35	88.27	88.27.1	20865	RIGHT FEMUR X-RAY	AP
					LL
36	88.27	88.27.1	20867	LEFT FEMUR X-RAY	AP
					LL
37	88.27	88.27.2	20873	RIGHT KNEE X-RAY	AP
					LL
38	88.27	88.27.2	20875	LEFT KNEE X-RAY	AP
					LL
39	88.27	88.27.3	20869	RIGHT LEG X-RAY	AP
					LL
40	88.27	88.27.3	20871	LEFT LEG X-RAY	AP
					LL
41	88.28	88.28.1	20943	RIGHT ANKLE X-RAY	AP
					LL
42	88.28	88.28.1	20945	LEFT ANKLE X-RAY	AP
					LL
43	88.28	88.28.2	20949	RIGHT FOOT X-RAY	PA
					LL
					OBL
44	88.28	88.28.2	20951	LEFT FOOT X-RAY	PA
					LL
					OBL
45	88.28	88.28.2	20939	RIGHT HEEL X-RAY	LL
					AX
46	88.28	88.28.2	20941	LEFT HEEL X-RAY	LL
					AX
47	88.29.2		21071	RIGHT AXIAL PATELLA X-RAY (3 projections)	AX
48	88.29.2		21073	LEFT AXIAL PATELLA X-RAY (3 projections)	AX
49	88.99.6	88.99.6	28421	BONE DENSITOMETRY – LUMBAR DXA	AP
50	88.99.7	88.99.7	28423	BONE DENSITOMETRY – FEMORAL DXA	AP

Tab. 1 - *Radiological practices accepted for standardization and related national and regional codes.*

amination and, where required, to maintain respiratory apnea (chest X-ray).

The TSRM on duty proceeded to position the patient appropriately, choose the most suitable CR cassette, set the acquisition parameters respecting the ALARA principle ("As Low As Reasonably Achievable"), that is, finding a fair compromise between the dose delivered to the patient and the quality of the images that would have been produced.

Following the dispensing, the values of the parameters set were pinned in a previously prepared facsimile, valid for all the devices and type of examination, in which any measures adopted for the correct execution of the survey were also reported, such as the use of the automatic light meter or the anti-diffusion grid (Tab. 2).

This procedure was repeated for at least 5 patients for each procedure in each of the devices, in order

EXAM DESCRIPTION	NUMERIC REGION CODE	SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)

AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	FOCUS DISTANCE SKIN (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTI-SCATTER GRID (YES/NO)	NUMBER OF PROJECTIONS	DAP (mGy·cm^2)

Tab. 2 - *Facsimile used for data collection.*

to collect a sufficient amount of data to be subjected to a careful statistical analysis and from which to extrapolate a reference protocol, useful for achieving the objective of the study.
Already in the data collection phase, traumatized and non-collaborating patients were excluded from the study and in the case of collaborating patients only the parameters for the acquisition of standard projections were pinned, eliminating from the investigation any special projections required for clinical questions and therefore focusing attention only on the "basic study" (the reason is explained below).
The equipment used is shown in Tab. 3.

At the end of the data collection phase, they were organized by anatomical district, by projection and location using the Excel facsimile (Table 3.2) thus facilitating the comparative analysis inter-presidium and intra-presidium.

At a first moment of the analysis phase, a careful selection of the data was made, discarding the parametric values that differed greatly from the average values, assuming that they were referred to non-normotype patients, obese or pediatric patients, who needed respectively overexposure and underexposure. On average, one, at most two patients per device who did not fall within the range of the remaining values collected were discarded.
The reason for the choices discussed above is linked to the rules dictated by the National Guidelines that speak of "standard protocols" understood as protocols referring to standard patients, with the characteristics of 170 cm in height and 70±15 kg in weight, subjected to the standard study of a given anatomical district, of which the Guidelines specify the number of standard projections.
The next step was to calculate the mathematical average of all the exposure and geometric parameters of each standard projection acquired for each district and for each type of equipment, approximating it by default or excess based on the result and which summarizes the work variability found in the various principals who contributed to the survey.
Starting from the standard protocols proposed in the next paragraph, it was possible to identify the dose class associated with each of them.
This last step was not easy because, since the equipment was not equipped with the DAP chamber (except for the densitometer), it was necessary to perform a series of calculations that led to the estimation of the effective dose relative to each projection of each protocol, using in part the indications contained in RP 154 (Tab. 4).

	SITE	MANUFACTURER	EQUIPMENT MODEL
TRADITIONAL RADIOLOGY	1, 2, 3, 4	GMS MED SRL	SIREVIX 180-Telecomandato
DENSITOMETRY	1, 3	HOLOGIC	DISCOVERY QDR
OPT	1	SIRONA	ORTOPHOS PLUS
	3	TOSHIBA	D-051 S

Tab. 3 - *Equipment referenced by the collected data*

CLASS	Effective dose (mSv)	Some examples
0	0	Ultrasound, MRI
I	<1	Chest X-ray, Limb X-ray, Pelvic X-ray, Cervical Spine X-ray
II	1-5	Abdomen X-ray, Urography, lumbar spine X-ray, CT scan (head and neck), Nuclear Med. (e.g. skeletal scintigraphy)
III	5-10	CT scan (chest and abdomen), some tests of Nuclear Med. (eg cardiac)
VI	>10	Some studies of Nuclear Med.
II-IV		Interventional Radiology

Tab. 4 - *E/DAP coefficients f om which to derive the effective dose in mSv.*

Calcolo Della Dose Efficace

The calculation of the effective dose involved the following steps:
Calculation of the efficiency of the tube as a function of kV, expressed in kerma in air at an FFD of 100 cm, according to the equation:

$$K_{(kVp)} = \left(1.222 - 5.664 * 10^{-2} kVp + 1.227 * 10^{-3} kVp^2 - 3.136 * 10^{-6} kVp^3\right) \left[\frac{mGy}{mA \cdot min}\right] \quad (1)$$

To convert mA·min to mAs, it was sufficient to divide the value of the yield obtained by 60.
Calculation of the kerma in air at an FFD=100 cm in mGy by multiplying the numerical value of the yield obtained from equation 11 by the mAs provided by the protocol of the procedure under consideration.

$$K_{a(100)} = K_{(kVp)} \cdot mAs \ \ [mGy] \quad (2)$$

Calculation of the kerma in air at an FFD≠100 cm: for radiological examinations acquired at a focus-detector distance greater than or less than 100 cm it was necessary to evaluate the K_a at that given distance d, applying the law of the inverse square of the distance

$$K_{a(d)} = K_{a(100)} \cdot \left(\frac{100}{d}\right)^2 [mGy] \quad (3)$$

Calculation of the DAP using the equation:

$$DAP = K \cdot A \ [Gy \cdot cm^2] \quad (4)$$

Calculation of the effective dose: the definition, from the literature, is $E = H \cdot W_T$ [Sievert], but to proceed with the calculation requires evaluations by a medical physicist. Therefore, to better approximate the calculation, the E/DAP coefficients (Table 3.4) included in the document "RP 154" were used, which consider the effective dose contribution of each organ of each organ. Note the DAP, it was sufficient to apply the reverse formula:

$$E = \frac{E}{DAP} \cdot DAP \ \ [\text{mSv}] \quad (5)$$

For densitometric examinations the calculation was simpler: since the equipment was equipped with the ionization chamber, it was enough to record the numerical value of the DAP reported by the machine and apply equation 4.
Given the effective dose value for each protocol, it was sufficient to compare it with the table of reference dose classes (Tab. 5), of the 2020 Intercompany Document on "Intercompany recommendations for dose class communication".

Exam type	E/DAP (mSv/Gy cm²)
1. Chest (PA + Lat) High kV Chest (PA + Lat) Low kV	0.18 0.10
2. Cervical spine	
3. Thoracic spine	0.19
4. Lumbar spine	0.21
6. Abdomen	0.26
7. Pelvis & hip	0.29
8. Ba meal	0.2
9. Ba enema	0.28
10. Ba follow	0.22
11. IVU	0.18
12. Cardiac angio.	0.2

Tab. 5 - *Dose classes*

Results: proposal of standard protocols

From the mathematical and critical analysis of the data, standard protocols were obtained that considered the methods of execution of radiographic examinations in all the devices taken into consideration, shown below by body district.
For the X-ray exams acquired with the remote controlled, since the same model is installed in all locations, two protocols have been drawn up for body district that consider the exposure and geometric parameters set, one by enabling the automatic light meter, the other working manually.

Skull District

For the cephalometric orthodontic study of the skull, for which OPT and teleradiography of the skull are foreseen, two different protocols have been extrapolated because, as reported in section 3.1, the equipment is different (Tables 6 and 7).

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
OPT		76	12	211	17,6	YES	60	35	18	33	YES
TELERADIOGRAPHY OF THE SKULL	PA	72	12	4,8	0,4	YES	120	95	24	30	NO
	LL	72	12	4,8	0,4	YES	120	95	24	30	NO

Tab. 6 - *Standard protocols for cephalometric X-ray study of the skull with OPT TOSHIBA*

EXAM DESCRIPTION	PROJECTION TYPE	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
OPT		71	13	195	15	YES	50	25	18	33	YES
TELERADIOGRAPHY OF THE SKULL	PA	75		25		YES	120	95	24	30	NO
	LL	75		25		YES	120	95	24	30	NO

Tab. 7 - *Standard Protocols For The Skull Cephalometric X-Ray Study With OPT SIRONA*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
SKULL AND PARANASAL SINUSES X-RAY	PA	70	100	50	0,5	YES	100	75	24	30	YES
	LL	60	100	40	0,4	YES	100	75	24	30	YES
	PA PAR. S.	73	100	35	0,35	YES	100	75	24	30	YES
NASAL BONES X-RAY*	LL	55	100	12	0,12	YES	100	85	18	24	YES
	AX	64	100	20	0,2	YES	100	85	18	24	YES
HEMIMANDIBLE X-RAY*	OBL	64	100	35	0,35	YES	100	90	18	24	YES

Tab. 8 - *Proposed standard protocols for the X-ray study of the skull and its structures without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
SKULL AND PARANASAL SINUSES X-RAY	PA	62	100	47	0,47	NO	100	75	24	30	YES
	LL	71	100	36	0,36	NO	100	75	24	30	YES
	PA PAR. S.	82	100	37	0,37	NO	100	75	24	30	YES
NASAL BONES X-RAY	LL	48	100	7	0,07	NO	100	85	18	24	NO
	AX	50	100	11	0,11	NO	100	85	18	24	NO
HEMIMANDIBLE X-RAY	OBL	69	100	30	0,3	NO	100	90	18	24	

Tab. 9 - *Proposed standard protocols for the X-ray study of the skull and its structures with AEC, ASL BT*

Rachis District

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
CERVICAL X-RAY	AP	73	100	27	0,27	NO	100	75	24	30	YES
	LL	72	100	27	0,27	NO	100	75	24	30	YES
DORSAL X-RAY	AP	75	100	37	0,37	NO	110	85	35	43	YES
	LL	78	100	38	0,38	NO	110	70	35	43	YES
LUMBAR X-RAY	AP	86	100	77	0,77	NO	110	85	35	43	YES
	LL	101	100	140	1,4	NO	110	70	35	43	YES

Tab. 10 - *Proposed standard protocols for the X-ray study of the spine without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
CERVICAL X-RAY*	AP	72	100	40	0,4	YES	100	75	24	30	YES
	LL	71	100	40	0,4	YES	100	75	24	30	YES
DORSAL X-RAY*	AP	74	100	60	0,6	YES	120	95	30	40	YES
	LL	80	100	74	0,74	YES	120	80	30	40	YES
LUMBAR X-RAY*	AP	80	100	70	0,7	YES	120	95	30	40	YES
	LL	90	100	90	0,9	YES	120	80	30	40	YES

Tab. 11 - *Proposed standard protocols for the X-ray study of the spine with AEC, ASL BT*

Thorax District And Rib Cage Structures

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
CHEST X-RAY	PA	105	150	8	0,08	NO	190	165	35	43	YES
	LL	111	150	21	0,21	NO	190	150	35	43	YES
HEMICOSTAT X-RAY	AP	76	100	34	0,34	NO	100	75	35	43	YES
	OBL	76	100	34	0,34	NO	100	75	35	43	YES
STERNUM X-RAY	OBL	76	100	44	0,44	NO	100	75	24	30	YES
	LL	80	100	48	0,48	NO	100	75	24	30	YES

Tab. 12 - *Standard protocols proposed for the X-ray study of the chest and bone structures of the rib cage without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
CHEST X-RAY*	PA	90	100	6	0,06	YES	150	125	35	43	YES
	LL	100	100	18	0,18	YES	150	110	35	43	YES
HEMICOSTAT X-RAY	AP	72	100	28	0,28	YES	135	110	35	43	YES
	OBL	76	100	28	0,28	YES	135	110	35	43	YES
STERNUM X-RAY*	LL	100	100	20	0,2	YES	150	125	24	30	YES

Tab. 13 - *Standard protocols proposed for the X-Ray study of the chest and bone structures of the rib cage with AEC, ASL BT*

Scapular Girdle District

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
SHOULDER X-RAY	AP INTRA	70	100	25	0,25	NO	105	85	24	30	YES
	AP EXTRA	70	100	25	0,25	NO	105	85	24	30	YES
CLAVICLE X-RAY	AP	71	100	17	0,17	NO	100	80	24	30	YES
	AX*	70	100	20	0,2	NO	100	80	24	30	YES
SCAPULA X-RAY	AP	64	100	30	0,3	NO	100	80	24	30	YES
	OBL	70	100	29	0,29	NO	100	75	24	30	YES

Tab. 14 - *Proposed standard protocols for the X-ray study of the bone structures that make up the shoulder girdle without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
SHOULDER X-RAY	AP INTRA	71	100	21	0,21	YES	110	90	24	30	YES
	AP EXTRA	71	100	21	0,21	YES	110	90	24	30	YES
CLAVICLE X-RAY	AP	58	100	22	0,22	YES	100	80	24	30	YES
	AX*	60	100	30	0,3	YES	100	80	24	30	YES
SCAPULA X-RAY*	AP	66	100	25	0,25	YES	100	80	24	30	YES
	OBL	76	100	40	0,4	YES	100	75	24	30	YES

Tab. 15 - *Proposed standard protocols for the X-ray study of the cone structures that make up the shoulder girdle with AEC, ASL BT*

Upper Limb District

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
HUMERUS X-RAY	AP	60	100	13	0,13	NO	100	85	35	43	YES
	LL	62	100	15	0,15	NO	100	85	35	43	YES
ELBOW X-RAY	AP	53	100	9	0,09	NO	100	90	24	30	NO
	LL	53	100	9	0,09	NO	100	90	24	30	NO
FOREARM X-RAY	AP	58	100	9	0,09	NO	100	90	35	43	NO
	LL	58	100	10	0,1	NO	100	90	35	43	NO
WRIST X-RAY	PA	51	100	6	0,06	NO	100	95	18	24	NO
	LL	51	100	6	0,06	NO	100	92	18	24	NO
HAND X-RAY	PA	50	100	5	0,05	NO	100	97	18	24	NO
	OBL	50	100	5	0,05	NO	100	95	18	24	NO

Tab. 16 - *Proposed standard protocols for the X-ray study of the upper limb without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
HUMERUS X-RAY	AP	68	100	15	0,15	YES	100	85	35	43	YES
	LL	75	100	15	0,15	YES	100	85	35	43	YES
ELBOW X-RAY*	AP	50	100	8	0,08	YES	100	90	24	30	NO
	LL	50	100	7	0,07	YES	100	90	24	30	NO
FOREARM X-RAY*	AP	48	100	7	0,07	YES	100	90	30	40	NO
	LL	48	100	7	0,07	YES	100	90	30	40	NO
WRIST X-RAY*	PA	45	100	4	0,04	YES	100	95	18	24	NO
	LL	45	100	4	0,04	YES	100	92	18	24	NO
HAND X-RAY*	PA	44	100	4	0,04	YES	100	97	18	24	NO
	OBL	44	100	4	0,04	YES	100	95	18	24	NO

Tab. 17 - *Proposed standard protocols for the X-ray study of upper limb with AEC, ASL BT*

Pelvis And Hip Joint District

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
PELVIS X-RAY	AP	83	100	37	0,37	NO	115	85	35	43	YES
HIP JOINT X-RAY	AP	80	100	45	0,45	NO	110	80	24	30	YES
	AX	83	100	45	0,45	NO	110	80	24	30	YES
SACROILIAC JOINT X-RAY	AP	81	100	49	0,49	NO	110	80	24	30	YES
	OBL	81	100	49	0,49	NO	110	70	24	30	YES

Tab. 18 - *Proposed standard protocols for the X-ray study of the pelvis and hip joint without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
PELVIS X-RAY*	AP	76	100	60	0,6	YES	110	80	35	43	YES
HIP JOINT X-RAY	AP	82	100	42	0,42	YES	100	70	24	30	YES
	AX	82	100	42	0,42	YES	100	70	24	30	YES
SACROILIAC JOINT X-RAY*	AP	74	100	60	0,6	YES	100	70	24	30	
	OBL	74	100	64	0,64	YES	100	60	24	30	

Tab. 19 - *Proposed standard protocols for the X-ray study of the pelvis and hip joint with AEC, ASL BT*

Lower Limb District

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
FEMORAL X-RAY	AP	72	100	36	0,36	NO	105	85	35	43	YES
	LL	71	100	36	0,36	NO	105	85	35	43	YES
KNEE X-RAY	AP	66	100	17	0,17	NO	100	85	24	30	YES
	LL	66	100	17	0,17	NO	100	85	24	30	YES
PATELLA X-RAY	AX	45	100	8	0,08	NO	100	85	18	24	NO
LEG X-RAY	AP	59	100	16	0,16	NO	100	85	35	43	NO
	LL	59	100	16	0,16	NO	100	85	35	43	NO
ANKLE X-RAY	AP	54	100	9	0,09	NO	100	90	24	30	NO
	LL	54	100	9	0,09	NO	100	90	24	30	NO
FOOT X-RAY	PA	51	100	9	0,09	NO	100	90	24	30	NO
	LL	53	100	9	0,09	NO	100	90	24	30	NO
	OBL	53	100	9	0,09	NO	100	90	24	30	NO
HEEL X-RAY	LL	49	100	10	0,1	NO	100	90	18	24	NO
	AX	51	100	11	0,11	NO	100	90	18	24	NO

Tab. 20 - *Proposed standard protocols for the X-ray study of the lower limb without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	FIELD SIZE (cassette) x	FIELD SIZE (cassette) y	ANTISCATTER GRID (YES/NO)
FEMORAL X-RAY*	AP	64	100	38	0,38	YES	120	100	35	43	YES
	LL	64	100	32	0,32	YES	120	100	35	43	YES
KNEE X-RAY*	AP	60	100	15	0,15	YES	100	85	24	30	NO
	LL	60	100	14	0,14	YES	100	85	24	30	NO
PATELLA X-RAY*	AX	60	100	12	0,12	YES	100	85	18	24	NO
LEG X-RAY*	AP	55	100	11	0,11	YES	120	105	35	43	NO
	LL	52	100	10	0,1	YES	120	105	35	43	NO
ANKLE X-RAY*	AP	46	100	6	0,06	YES	100	90	24	30	NO
	LL	46	100	6	0,06	YES	100	90	24	30	NO
FOOT X-RAY*	PA	45	100	5	0,05	YES	100	90	24	30	NO
	LL	45	100	5	0,05	YES	100	90	24	30	NO
	OBL	45	100	5	0,05	YES	100	90	24	30	NO
HEEL X-RAY*	LL	46	100	6	0,06	YES	100	90	18	24	NO
	AX	50	100	12	0,12	YES	100	90	18	24	NO

Tab. 21 - *Proposed standard protocols for the X-ray study of the lower limb with AEC, ASL BT*

Densitometry

EXAM DESCRIPTION	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	AEC (YES/NO)	DETECTOR FOCUS DISTANCE (cm)	DETECTOR SKIN DISTANCE (cm)	DAP ($mGy \cdot cm^2$)
LUMBAR DENSITOMETRY	AP	105	125	2,5	50	YES	20,4	11,4	2,3
FEMORAL DENSITOMETRY	AP	105	125	2,5	50	YES	20,4	11,4	2,3

Tab. 22 - *Proposed standard protocols for lumbar and femoral densitometric study, ASL BT*

*Note: the proposed protocol is based on the acquisition of a single acquisition protocol registered in a garrison

RESULTS: EFFECTIVE DOSES AND DOSE CLASS

Skull District

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
OPT		76	211	0,4	I
TELERADIOGRAPHY OF THE SKULL	PA	72	4,8	0,006	I
	LL	72	4,8		

Tab. 23 - *Verification of effective dose and dose class of the cephalometric orthodontic study of the skull with OPT TOSHIBA*

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
OPT		71	195	0,57	I
TELERADIOGRAPHY OF THE SKULL	PA	75	25	0,03	I
	LL	75	25		

Tab. 24 - *Verification of effective dose and dose class of the skull orthodontic cephalometric RX study with OP SIRONA*

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
SKULL AND PARANASAL SINUSES X-RAY	PA	62	47	0,093	I
	LL	71	36		
	PA PAR. SI-NUESES	82	37		
NASAL BONES X-RAY	LL	48	7	0,03	I
	AX	50	11		
HEMIMANDIBLE X-RAY	OBL	69	30	0,013	I

Tab. 25 - *Verification of effective dose and dose class of the standard X-ray study of the skull and its structures without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
SKULL AND PARANASAL SINUSES X-RAY	PA	70	50	0,086	I
	LL	60	40		
	PA PAR. SINU-SES	73	35		
NASAL BONES X-RAY	LL	55	12	0,007	I
	AX	64	20		
HEMIMANDIBLE X-RAY	OBL	64	35	0,013	I

Tab. 26 - *Verifica ion of effective dose and dose class of the standard X-ray study of the skull and its structures with AEC, ASL BT*

Rachis District

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
CERVICAL X-RAY	AP	73	27	0,198	I
	LL	72	27		
DORSAL X-RAY	AP	75	37	0,79	I
	LL	78	38		
LUMBAR X-RAY	AP	86	77	4,07	II
	LL	101	140		

Tab. 27 - *Verification of effective dose and dose class of the standa d X-ray study of the spine without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
CERVICAL X-RAY	AP	72	40	0,29	I
	LL	71	40		
DORSAL X-RAY	AP	74	60	0,96	I
	LL	80	74		
LUMBAR X-RAY	AP	80	70	1,6	II
	LL	90	90		

Tab. 28 - *Verification of effective dose and dose class of the standa d X-ray study of the spine with AEC, ASL BT*

Thorax District And Rib Cage Structures

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
CHEST X-RAY	PA	105	8	0,135	I
	LL	111	21		
HEMICOSTAT X-RAY	AP	74	39	0,58	I
	OBL	74	39		
STERNUM X-RAY	OBL	76	44	0,37	I
	LL	80	48		

Tab. 29 - *Verification of effective dose and dose class of the standard X-ray study of chest and rib cage bone structures without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
CHEST X-RAY	PA	90	6	0,12	I
	LL	100	18		
HEMICOSTAT X-RAY	AP	72	28	0,23	I
	OBL	76	28		
STERNUM X-RAY	LL	100	20	0,06	I

Tab. 30 - *Verification of effective dose and dose class of the standard X-ray study of chest and rib cage bone structures with AEC, ASL BT*

Pelvis And Hip Joint District

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
PELVIS X-RAY	AP	83	37	0,65	I
HIP JOINT X-RAY	AP	80	45	0,79	I
	AX	83	45		
SACROILIAC JOINT X-RAY	AP	81	49	0,86	I
	OBL	81	49		

Tab. 31 - *Verification of effective dose and dose class of the standard X-ray study of the pelvis and hip joint without AEC, ASL BT*

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
PELVIS X-RAY	AP	76	60	0,95	I
HIP JOINT X-RAY	AP	82	42	0,9	I
	AX	82	42		
SACROILIAC JOINT X-RAY	AP	74	60	1,07	II
	OBL	74	64		

Tab. 32 - *Verification of effective dose and dose class of the standard X-ray study of the pelvis and hip joint with AEC, ASL BT*

Densitometry

EXAM DESCRIPTION	PROJECTION TYPE	kV	mAs	EFFECTIVE DOSE (mSv)	DOSE CLASS
LUMBAR DENSITOMETRY	AP	105	2,5	0,0005	I
FEMORAL DENSITOMETRY	AP	105	2,5	0,0005	I

Tab. 33 - *Verification of effective dose and dose class of lumbar and femoral densitometric stud , ASL BT*

DISCUSSION

From the examination of the data collected and the standard protocols proposed, the following considerations emerged.

Skull District

In the study of the skull for orthodontic cephalometry the two proposed protocols show slight differences due to the different equipment installed (see Tables 6 and 7).

From the examination of the data collected for the X-ray study of the skull and paranasal sinuses it emerged that for the acquisition of the "PA paranasal sinuses" projection the data are overlapping with each other, with a 17% increase in kV in the site 1 compared to 2, while there is an increase in mAs not insignificant (about 39%) in the standard PA projection of the skull (see Table 34).

SITE	PROJECTION TYPE (AP/ LAT/OBL)	kV	mAs
1	PA	80	50
	LL	65	40
	PA PAR. SIN.	82	35
2	PA	70	36
	LL	70	36
	PA PAR. SIN.	70	36

Tab. 34 - *Data collected for the X-ray study of skull and paranasal sinuses without AEC with more recurrent kV and mAs*

Below are the most frequent values for the acquisition of an occipital-nose-chin projection for the paranasal sinuses, with AEC (Table 35): you immediately notice the difference between the mAs in sites 3 and 4 in which, with the same mA, the automatic exposure system blocks the beam delivery after a different exposure time of about 0.25 s, thus causing an increase in mAs in site 4 compared to 3. Assuming that the AEC is calibrated correctly, these differences are attributable to the different physiognomy of the patients.

SITE	PROJECTION TYPE (AP/ LAT/OBL)	kV	mA	mAs
3	PA	75	100	32
4	PA	64	100	50

Tab. 35 - *Data collected for the X-ray study of paranasal sinuses with AEC with more recurrent kV and mAs*

As for the remaining acquisition parameters, they have not been reported because they remain constant in all principals and for all projections, whether they are acquired with AEC or in manual mode and are reported in the standard protocol in Tables 3.8 and 3.9.

Since the exposure dose of the patient undergoing an X-ray examination depends on the parameters set and these are very close to each other, the difference in terms of effective dose associated with the protocol with and without AEC is equal to 0.07 mSv (see Tables 25 and 26).

From Table 3.36 below, relating to the acquisition data of an X-ray of the nasal bones, it emerges that

the same criticality discussed for the skull RX study recurs, that is, a double or triple increase of mAs in the site 1, compared to garrison2.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs
1	LL	50	15
	AX	50	15
	LL	55	12
	AX	55	12
2	LL	45	5
	AX	45	5

Tab. 36 - *Examples of data collected for the X-ray study of nasal bones without AEC*

It was not possible to make a comparison between standard protocols with and without AEC because only one case was recorded in a single X-ray study of the nasal bones with AEC that was excluded from the evaluation.
About the "X-ray hemimandible" examination (Table 3.37), the minimum value of the mAs set is recorded in presidium 2 (10 mAs) against a maximum value of 40 mAs recorded in presidium 1 and parallel to a disuniformity of set kV values (from 55 to 75) and mAs (from 10 to 40).

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs
1	OBL	75	40
2	OBL	55	10

Tab. 37 - *Most recurrent data recorded for the X-ray study of hemimandible without AEC*

Rachis District

In the LL projections for the X-ray study of the cervical spine there are inconsistencies between the mAs and kV set in the various sites that do not use the AEC that are found in Table 3.38 below, which shows the most frequent data for the acquisition of a cervical X-ray. There is a clear difference in mAs (20 mAs to 32 mAs) and kV (60 to 85) set in both AP and LL projection.
As mentioned before, this difference cannot be linked to the type of equipment as the same models of the remote controlled are installed but could be linked to the physical characteristics of the patient examined or perhaps to the clinical question that requires visibility of the smallest anatomical detail and therefore a different combination of kV and mAs. In addition to an inter-presidium variation, it can be noted that there is a difference in mAs also in the acquisition of an X-ray in the same hospital site, as happens in the site 3 or even more in site 1; it is also noted that an increase in mAs is always accompanied by a decrease in kV, following the "dose optimization rules".

SITE	PROJECTION-TYPE (AP/LAT/OBL)	kV	mAs
1	AP	75	30
	LL	75	30
	AP	85	20
	LL	85	20
2	AP	60	20
	LL	60	20
3	AP	70	25
	LL	70	25
	AP	60	32
	LL	60	32

Tab. 38 - *Examples of kV and mAs for the X-ray study of the cervical spine without AEC*

For all other parameters, however, there is a repeatability in all sites, with values that have flowed directly into the standard protocol shown in Table 3.10.
The same criticalities are found in the execution of the radiological investigation on the dorsal spine without AEC: as for the cervical, both in the AP and LL projection there is a higher value of the mAs in the 1 and 2 sites compared to 3. In addition, only two cases out of five investigated in the site 1 are reported, showing that the data are different (Table 39). It is reiterated that these differences could be attributable to the different physiognomy of the patient under study.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs	DETECTOR FOCUS DISTANCE (cm)
1	AP	85	30	100
	LL	85	30	100
	AP	75	55	100
	LL	75	55	100
2	AP	75	40	100
	LL	80	50	100
3	AP	73	32	120
	LL	77	32	120

Tab. 39 - *Examples of data collected for the RX study of the dorsal spine without AEC*

Another inconsistency concerns the fire-detector distance which in the site 3 is 120 cm, in the remaining two it is 100 cm. Usually the increase in distance compared to 100 cm serves to compensate for the distance of the structure under examination (in this case the dorsal) from the sensitive plane which, not being in contact with it, would be enlarged even if slightly, considering a difference of only 20 cm. Since the choice is of the TSRM, these variations are operator dependent.

Analyzing the data collected for the lumbar examination, differences are confirmed not only in terms of mAs, but also of kV (see Table 40) between several examinations performed in the same hospital, as well as between different devices.

SITE	PROJECTION TYPE (AP/ LAT/OBL)	kV	mAs	DETECTOR FOCUS DISTANCE (cm)
1	AP	100	80	100
	LL	110	80	100
	AP	85	100	100
	LL	95	200	100
2	AP	75	55	100
	LL	90	80	100
3	AP	90	100	120
	LL	117	250	120

Tab. 40 - *Examples of data collected for the lumbar spine X-ray study without AEC*

The LL projection, which is usually the one that requires the greatest dose because the X beam must pass through a high thickness rich in high-density bone structures, is performed by even setting a triple mAs value for some patients (see 250 mAs in the site 3) compared to a minimum value of 80 mAs (sites 1 and 2). This happens not only in different facilities, but also in the same hospital: it is noted, for example, that in site 1 to acquire a LL of the lumbar in the first case 80 were dispensed and in the second 200 mAs, more than double compared to the previous one.
The same problem was found in the analysis of kV: there is a difference of about 30 kV in the AP projection between sites 1 and 2 and in the LL between 2 and 3, which could be justified by the clinical question of the tests as working at a lower kilovoltage involves increasing the contrast of the image.
Using a different focus-detector distance could follow the same logic described in the study of the spine.
The use of AEC is convenient from a dosimetric point of view and in Tables 27 and 28 the clear difference between the effective dose values is visible, which triples in the protocol without AEC: although the associated dose class coincides with that indicated in the Intercompany Document, the effective dose value is higher than those present in the literature.

Thorax District And Rib Cage Structures

In the analysis of the data of the protocols recorded for the examination of the chest, it can be deduced that the deviations of the kV between the various devices are minimal and not very relevant both in the PA and LL projection (see Table 41); the same cannot be said for the mAs: taking into consideration sites 1 and 2, for the acquisition of the PA projection the different milliamperage set is compensated with the exposure time such that the product of the two parameters (mAs) remains constant and unchanged. In the LL projection, on the other hand, this compensation is less: in site 1 at least twice as many mAs are delivered compared to site 2 with an increase in the dose of exposure to the patient that cannot be justified by the different clinical question investigated because, if this were the case, the non-increase of mAs in the AP projection would not be explained.

The most appropriate term for this type of examination is *teleradiography of the chest* since it is acquired with a focus-detector distance greater than 100 cm (conventional distance for all other districts) to represent the heart in a dimension as close as possible to the real one, as it is not in direct contact with the detector due to the conical geometry of the incident beam, It would be magnified by simulating a heart disease and thus leading to false positives. Usually, the X-ray tube is removed from 150 to 200 cm from the detector because doing so reduces the divergence of the beam and therefore the magnification, without ever exceeding this limit because for distances greater than 200 cm the patient would be exposed to an unjustified dose as the distance increases it would be necessary to increase the dose to compensate for the lost photons. The TSRM plays a fundamental role in the implementation of the optimization principle, finding a fair compromise between exposure dose and image quality, setting in this specific case an intermediate distance of about 180 cm. This could be an explanation for the difference in mAs between sites 1 and 2 reported in the acquisition of a chest LL: setting a greater distance (200 cm vs 180 cm) would explain the increase in dose. Looking at Table 3.41 we note

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mA	mAs	EXPOSURE TIME (s)	DETECTOR FOCUS DISTANCE (cm)	AEC (YES/NO)
1	PA	100	200	12	0,06	200	NO
	LL	120	200	40	0,2	200	NO
	PA	90	200	15	0,075	200	NO
	LL	110	200	50	0,25	200	NO
2	PA	80	100	12	0,12	180	NO
	LL	90	100	20	0,2	180	NO
4	PA	90	100	6	0,06	150	YES
	LL	100	100	18	0,18	150	YES

Tab. 41 - *Examples of data collected for the chest X-ray study with and without AEC*

that all the devices fall within the range of distances mentioned above, with the difference that at 150 cm the heart has a projective size greater than it would have at 200 cm.
Since the hospital site 4 is the only one to use the AEC, the standard protocol obtained is given by the average of the values set for the execution of chest X-ray examinations only in this garrison: comparing it to that obtained from the acquisitions performed without AEC (Table 3.12) it is noted that they are very similar, making the choice to use the AEC almost irrelevant. The effective dose values calculated for the patient with a protocol with and without AEC, in fact, do not differ much, but the optimal choice would be to find a fair compromise between the two because, with the same kV and mAs and therefore image quality, working with the AEC enabled but at an FFD (focus-film distance) of 190 cm (as for the standard protocol without AEC), There would be two advantages:
representation of the heart in its real dimensions;
dose reduction to the patient: the associated effective dose would be 0.093 mSv, 0.042 mSv lower than AEC protocol and 0.027 lower than AEC protocol.
Continuing, the problems encountered in the elaboration of the standard protocols of the bone structures of the rib cage are discussed.
From the analysis of the parameters set in manual mode (kV and mAs) for the X-ray study of the hemicostate, presented in Table 42 below, it was deduced that in the first unit there is a variability of kV (of 21%) both in the AP and OBL projection and of mAs (of 60%). However, the data have been ordered in such a way as to highlight how the decrease in kV corresponds to a progressive increase in mAs according to the 15% rule and is a measure aimed at guaranteeing on the one hand an acceptable image quality in patients who have different physicality, on the other a dose saving.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs
1	AP	85	20
	OBL	85	20
	AP	80	25
	OBL	80	25
	AP	70	50
	OBL	70	50

Tab. 42 - *kV e mAs collected for the X-ray study of right and left hemicostat without AEC in site 1*

The 15% rule appears to have been applied also in the AEC study in site 3 (see Table 43 below). The most significant criticality is the difference in kV but above all in mAs that is observed between the two devices that use the AEC: the reduction of kV compared to the site 3 (about 14%) is accompanied by an exaggerated increase in mAs (by 253%). Since only one protocol for device 4 is registered, it is not possible to trace the causes of these differences: it cannot be said with certainty whether they depend on the functioning of the AEC, nor if they are data referring to a normal or large patient who does not fall within the standard and who should therefore be excluded from the study.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs
3	AP	70	17
	OBL	75	17
	AP	80	20
	OBL	85	20
4	AP	60	60
	OBL	60	60

Tab. 43 - *Examples of data collected for the acquisition of an hemicostat X-ray with AEC*

Comparing the standard protocols proposed in Tables 3.12 and 3.13, we observe a 17% reduction in mAs and an increase from 100 to 135cm in the fire-detector distance in the protocol with AEC. Tables 3.29 and 3.30 report the effects on effective dose of these differences that make the AEC protocol more advantageous than the one without, with a dose saving to the patient of 60%.
The analysis of the data collected for the sternum X-ray examination confirms the considerations made previously for the hemicostat X-ray study: if in site 2 there is a constancy in the setting of kV and mAs, in site 1 there is a variability in the combination of kV and mAs that meets the rule of 15%.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs
1	OBL	85	30
	LL	85	30
	OBL	80	40
	LL	80	40
	OBL	75	50
	LL	75	50
2	LL	90	60
	OBL	70	40

Tab. 44 - *Examples of data collected for sternum X-ray study*

Scapular Girdle District

Analyzing the data collected for the shoulder X-ray study, some of which are shown in Table 3.45 below, it was found that:
sites 1 and 2 always work without AEC, setting kV and mAs that vary according to the 15% rule in the first case, rather constant in the second;
site 3 in 60% of cases does not use the AEC;
site 4 always uses the AEC;
in protocols without AEC there is a maximum deviation of 28% between the set kV and 60% between the mAs; with AEC, on the other hand, there is a repeatability of the data;
the focus-detector distance is slightly greater at site 3 than at the others, as can be seen from Table 45.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs	EXPOSURE TIME (s)	DETECTOR FOCUS DISTANCE (cm)	AEC (YES/NO)
1	AP INTRA	75	30	0,3	100	NO
	AP EXTRA	75	30	0,3	100	NO
	AP INTRA	70	20	0,2	100	NO
	AP EXTRA	70	20	0,2	100	NO
2	AP INTRA	60	20	0,2	100	NO
	AP EXTRA	60	20	0,2	100	NO
3	AP INTRA	77	32	0,32	120	NO
	AP EXTRA	77	32	0,32	120	NO
3	AP INTRA	70	20	0,2	120	YES
	AP EXTRA	70	20	0,2	120	YES
4	AP INTRA	70	20	0,2	100	YES
	AP/EXTRA	70	20	0,2	100	YES

Tab. 45 -. *Examples of data collected for the shoulder X-ray study with and without AEC*

For the drafting of a standard protocol for the "X-ray clavicle" examination without AEC no difficulties were encountered, thanks to the concordance between the parameters set; the same cannot be said for the protocol with AEC in which it was necessary to find a fair compromise between the two devices that use it because with the same kV and mA, the automatic exposure system causes the exposure time to double in one case compared to the other (Table 46).

SITE	PROJECTION TYPE (AP/ LAT/OBL)	kV	mA	mAs
3	AP	60	100	15
4	PA	60	100	30

Tab. 46 - *Different mAs values delivered with AEC*

The most important discrepancy can be seen between the types of projections: in site 4 it is preferred to acquire in PA rather than in AP, which is not an aspect on which to dwell too much because from the textbook they are both valid projections with the same radiographic result, improving the visibility of the structures most in contact with the sensitive plane that is the sterno-clavicular joint in the first case, the acromion-clavicular in the second.
Examining the data collected for the scapula X-ray study without AEC (see Table 47) the only criticality that emerged is that with the same kV and geometric factors, the mAs set in site 2 are 40% lower in the AP projection and 52% lower in the OBL projection compared to the site 1.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs
1	AP	60	40
	OBL	65	50
2	AP	60	24
	OBL	60	24

Tab. 47 - *Data collected for the scapula X-ray study without AEC, with more recurrent kV e mAs*

Upper Limb District

In the study of humerus, elbow, forearm, wrist and hand, the choices of all exposure parameters (kV, mAs), geometric (fire-detector distance and fire-skin) and dose optimization techniques (use of the anti-diffusion grid) are superimposable whether they are acquired with AEC or not (Tables 3.16 and 3.17). In the choice of the CR cassette there are minimal differences (24x30 or 18x24) for the acquisition of an hand or wrist X-ray depending on the size of the district under study: it is an irrelevant detail because by appropriately matching the beam the dimensions of the FOV are limited only to the structure of interest.
The effective dose values of the X-ray studies of the shoulder girdle and upper limb are not reported in the "Results" section because there are no reference documents in the literature to allow their calculation, probably because the effective dose contribution of an RX of an upper limb district is minimal and consequently we can assume that it falls into *dose class I* . Although we do not have real numerical values to estimate the effective dose, it is possible to hypoth-

esize which of the two protocols proposed for each district (with and without AEC) is more convenient with a view to optimizing the dose to the patient, if both produce qualitatively diagnostic images.
Following the steps for the calculation of the effective dose described in section 3.1 starting from the exposure and geometric data of the standard protocols and indicating the *E/DAP* ratio relative to any district with a constant *k,* it can be deduced that in most cases the best dosimetric result is that offered by the protocol with AEC. The following is an example, which can be extended to all the remaining districts (Table 48).

SHOULDER X-RAY WITHOUT AEC	SHOULDER X-RAY WITH AEC
E = k·1,194 mSv	*E = k·0,942 mSv*

Tab. 48 - *Comparison of effective dose values of shoulder X-ray protocols with and without AEC*

Pelvis And Hip Joint District

The most frequent data for the X-ray study of the pelvis without AEC (shown in Table 3. 49) show a difference of 22% in kV and 36% in mAs, most likely linked to the different physiognomy of the patients under examination.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs	DETECTOR FOCUS DISTANCE (cm)
1	AP	78	50	100
2	AP	70	40	120
3	AP	90	32	120

Tab. 49 - *Data collected for the X-ray pelvis study without AEC, with more recurrent kV and mAs*

The same goes for the AP and AX projections of hip without AEC and with AEC (Table 50), with a variation of kV respectively of 17% and 22% and mAs around 32/33% in both cases: it should be noted, however, that the increase in kV corresponds to the reduction of mAs and vice versa to ensure the right compromise between dose and image quality.
The focus-detector distance chosen varies between 100 and 120 cm for the pelvis and between 100 and 110 cm for the hip for the same reasons and with the same consequences explained above (see respectively "dorsal Rx study").
Reasoning in terms of dose savings to the patient, the comparison between Tables 31 and 32 shows that the protocol with AEC is disadvantageous compared to the one without; in reality it is a result influenced by the shorter focus-detector distance set compared to that without AEC: in fact, placing itself in the same geometric conditions of the protocol without AEC (FFD = 110 cm) and delivering the beam with kV and mAs proposed in the protocol with AEC, the patient would be subject to an effective dose equal to 0.74 mSv, lower than the value associated with the protocol without AEC proposed.LOWER

Limb District

Analyzing the data collected for the X-ray study of all districts of the lower limb, it emerged that the AEC is used only in site 4 for which in most cases only one protocol is reported, thus making it impossible to draw up a protocol with reliable AEC. From the data collected in the facilities that do not use the AEC, critical issues emerged that were not different from those previously found, with a variability of kV and mAs both intra-headquarters and inter-headquarters and in particular in site 2, where work is carried out at a milliamperage higher than the others. Table 51 gives an example.

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs
1	AP	65	8
	LL	65	8
2	AP	55	24
	LL	55	24

Tab. 51 - *Difference in mAs between two principals in the X-ray leg study without AEC*

SITE	PROJECTION TYPE (AP/LAT/OBL)	kV	mAs	DETECTOR FOCUS DISTANCE (cm)	AEC (YES/NO)
1	AP	85	50	100	NO
	AX	85	50	100	NO
2	AP	70	34	110	NO
	AX	80	34	110	NO
3	AP	90	40	100	YES
	AX	90	40	100	YES
4	AP	70	60	100	YES
	AX	70	60	100	YES

Tab. 50 – *Data collected for the hip joint X-ray study without and with AEC, with more recurrent kV and mAs*

For the same reasons expressed for the "upper limb" district it was not possible to calculate the specific effective dose values for the lower limb (which falls within dose class I) but starting from the proposed protocols (Tables 20 and 21), applying the procedure illustrated in section 3.1 "Materials and Methods" it can be assumed that, as in most cases, the use of AEC is advantageous with a view to dose optimization.

E OF ANKLE X-RAY WITHOUT AEC	E OF ANKLE X-RAY WITH AEC
E= k·0,27 mSv	*E= k·0,13 mSv*

Tab. 52 *-. Comparison of effective dose values of ankle X-ray protocols with and without AEC*

CONCLUSION

The study conducted, based on the general analysis of the data collected in the Radiology Services of the entire ASL BT and the standard protocols proposed from them, led to the following conclusions.

This thesis represents the proposal of 33 standard protocols for the execution of radiological practices on OPT, densitometry and remote-controlled equipment installed in the ASL BT facilities;

The dose classes associated with the proposed standard protocols relating to radiological examinations conducted on a single remote-controlled model in use in the 4 Radiology Services of the ASL BT were verified. It will be necessary to proceed with a similar analysis on the remaining equipment.

The dose classes associated with the proposed standard protocols relating to radiological examinations conducted on a single densitometer model and two different OPT equipment in use in the Radiology Services of the ASL BT were verified;

A repetitive operator-dependent variability emerged between different devices and in the same garrison, mainly linked to the setting of kV and mAs, the combination of which, however, in most cases follows the rules of optimization of the dose to the patient. The remaining parameters, both exposure and geometric, are kept rather constant with some exceptions in the focus-detector distance and in the use of the anti-diffusion grid;

Whenever possible, the study showed that AEC always results in dose savings to the patient;

The dose classes associated with the standard protocols agree with the reference classes, reported in the "Intercompany Document for the communication of the dose class";

In the ASL BT healthcare company it is possible to proceed with the implementation of the Guidelines for all the identified practices admitted to standardization, provided with the equipment analyzed in this work;

Although it has not been possible to propose a standard protocol with AEC for all standardized radiological procedures due to the lack of tests performed with the use of AEC, the AEC examination recorded on a single patient is sufficient to demonstrate the dose reduction that its use entails. An exception is the RX study of the sacroiliac joint in which the examined patient is supposed not to fall within the standard.

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