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Research Article

Plain radiography has a role to play in current clinical practice in Western Switzerland

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ABSTRACT

Aim: The aim of the study was to investigate the current role of conventional radiography examinations in Western Switzerland and the main clinical indications required to justify the use of this imaging examination.

Methods: Ethical approval was obtained from Vaud Ethics committee (Ref 2020–00311). An online questionnaire was specifically designed and implemented on the data collection tool LimeSurvey composed of two parts: a) to characterise the participants' profile and their institutions and b) 169 projections for the different anatomical area (upper and lower limbs, pelvis, skull, spine, thorax, abdomen) were presented to collect data about the frequency and main clinical indications. Statistical analysis was performed using the software IBM SPSS® (Statistical Package for the Social Sciences) version 26.

Results: Radiographers from 60% (26/43) of the invited institutions participated in this survey, mainly from Vaud region. The upper and lower limbs were the most commonly examined by using conventional radiography mainly for trauma and degenerative disorders. The thorax was also an anatomical area commonly explored by X-rays, so were the spine (cervical and lumbar lateral). The skull radiographs were rarely performed in clinical practice and some of the projections were not being used, namely Hirtz, Tangential Nose Bones, Worms and Caldwell's views.

Conclusions: Plain radiography is being used in clinical practice mainly for appendicular skeleton studies and for trauma and degenerative pathologies. Adaptations in radiographers' education and training and other healthcare professionals are needed to provide the judicious use of data that radiographs can give to better manage the patients' imaging pathway.

RÉSUMÉ

But: Le but de l'étude était d'étudier le rôle actuel des examens de radiographie conventionnelle en Suisse occidentale et les principales indications cliniques requises pour justifier l'utilisation de cet examen d'imagerie.

Méthodologie: L'approbation éthique a été obtenue auprès de la Commission d'éthique du canton de Vaud (Ref 2020-00311). Un questionnaire en ligne a été spécifiquement conçu et implémenté sur l'outil de collecte de données LimeSurvey composé de deux parties: a)

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caractériser le profil des participants et leurs institutions et b) 169 projections pour les différentes zones anatomiques (membres supérieurs et inférieurs, bassin, crâne, colonne vertébrale, thorax, abdomen) ont été présentées pour recueillir des données sur la fréquence et les principales indications cliniques. L'analyse statistique a été réalisée à l'aide du logiciel IBM SPSS® (Statistical Package for the Social Sciences) version 26.

Résultats: Des radiographes de 60 % (26/43) des institutions invitées ont participé à cette enquête, principalement de la région vaudoise. Les membres supérieurs et inférieurs étaient les plus fréquemment examinés par radiographie conventionnelle, principalement pour les traumatismes et les troubles dégénératifs. Le thorax était également une zone anatomique couramment explorée par radiographie, de même que la colonne vertébrale (cervicale et lombaire latérale). Les radiographies du crâne étaient rarement réalisées en pratique clinique et certaines projections n'étaient pas utilisées, notamment les vues de Hirtz, des os du nez tangentiels, de Worms et de Caldwell.

Conclusions: La radiographie simple est utilisée en pratique clinique principalement pour les études du squelette appendiculaire et pour les traumatismes et les pathologies dégénératives. Des adaptations dans la formation des radiographes et des autres professionnels de la santé sont nécessaires pour permettre une utilisation judicieuse des données que les radiographies peuvent fournir afin de mieux gérer le parcours d'imagerie des patients.

Keywords: Radiology; Radiographers; Medical imaging examinations; Upper and lower limbs; Extremities; Abdomen; Chest; skull

Introduction

Plain Radiography is an imaging modality routinely performed despite the superposition of structures and the low sensibility and specificity to study soft tissues or vascular structures. This imaging modality allows the prompt diagnosis and follow up of fractures, infections, chronic, degenerative, and congenital disorders, in emergency or follow up settings [1]. The main advantages of using plain radiography are due to prompt answer to a clinical question to avoid exploratory surgeries, the wide availability, clinicians' familiarity with the procedure and inexpensive nature [2–5]. However, the technological evolution and the introduction of sectional imaging modalities such as computed tomography (CT), magnetic resonance imaging (MRI) or positron emission tomography (PET) have made significant changes in clinical practice [6] and nowadays the limitations of plain radiography for superimposition, soft and vascular tissues are being overcome. Nevertheless, CT examinations are associated with higher radiation dose compared to plain radiography, it also has limitations in studying soft tissues [7]. MRI is not widely available, and it is more expensive, requiring longer acquisition time [8].

The Swiss studies [9,10]. about the use of medical imaging modalities showed that the number of imaging examinations executed in Switzerland increased from 2008 to 2013, leading to an increase in the average annual effective dose per inhabitant [9,10]. Dental radiography, CT and mammography are identified as the most common examinations, but plain radiography has showed a reduction of 44% between 2008 and 2018 [11].

Despite the above-mentioned benefits of using these medical imaging modalities, there are risks associated with the ionising radiation with CT as the major contributor [9,10]. Justification and optimisation of radiological procedures are the main strategies recommended by the International Commission on Radiological Protection to reduce the radiation dose to the population [12–15]. Justification principle means that a radiological examination must be medically indicated and must be useful and an add-value to the patient, providing more good than harm and avoiding unnecessary radiation exposure in many cases. Considerations about available resources should also be included in the decision-making process [15,16]. as well as the patient condition. In the published literature there is a gap on the role of plain radiography in the current clinical settings considering all the technological evolution. There are available some studies that presented the advantages and the limitations of this medical imaging method [17–24], but not an overview about its current use for all anatomical regions and the main clinical justifications presented in the referral. Since the examination numbers for this modality have also been reduced in Switzerland, it is important to identify which radiographs are still pertinent for practice to help direct the positioning training for medical imaging students as well as the optimisation studies to keep the dose as lower as possible.

This study aimed to explore the role of plain radiology in Western Switzerland and the main clinical indications typically needed to justify the use of this imaging modality in daily clinical practice.

Methodology

An online questionnaire was specifically designed on LimeSurvey. It aimed to explore the main plain radiography projections used in the main hospitals and clinics that are currently collaborating with Higher Educational Institutions (HEI) in Western Switzerland (inclusion criteria), as well as the typical justifications provided in the referrals submitted to radiographers. The questionnaire included mainly closed-ended questions and 2 open-ended questions to give the opportunity to add additional information about the clinical practice regarding plain radiography. The questionnaire was composed of two parts. The first part aimed to characterise the participants profile and their institutions. In the second part, the projections for each anatomical area (upper and lower limbs, skull, spine, thorax, abdomen) were presented to collect data about the frequency of each projection as well as the main clinical indications for each projection. The 169 projections were identified in a previous literature search and on the clinical routines of the university hospitals that collaborate closely with HEIs [25,26].

Prior to the distribution, the questionnaire was reviewed by four academics with medical radiation science backgrounds, and it was also piloted by radiographers in clinical practice to verify content and semantic. Suggestions were included when appropriate to improve the tool. The questionnaire was distributed by emailing to all the 43 tutors of clinical practice and social media were also used to increase the participants response rate through the Swiss Association of Radiographers (ASTRM), the University of Applied Sciences and Arts Western Switzerland (HES-SO) and LinkedIn in according to the recommendations from Agency for Healthcare Research and Quality. Recalls were made by email and social media.

Considering this is an exploratory study, descriptive statistics were performed using the software IBM SPSS® (Statistical Package for the Social Sciences) version 26. To study the different practices between public and private facilities, the frequency of radiological incidences was calculated as well as if these frequencies were statistically significant ($p<0.05$) by using a Fisher exact test and Cramer's V to measure the effect size.

This survey was part of a larger project that received ethical approval prior to the study from Vaud Ethics committee (Ref 2020–00,311), informed consent was required to all participants and anonymity was assured as well as data protection.

Results

The questionnaires were answered by 26 (out of 43) radiographers working in plain radiography rooms in Western Switzerland (Vaud, Neuchatel, Geneva, Jura). The main activities performed in their practice were in central departments for routine and follow up examinations (84.6% and 76.9% respectively), emergency (61.5%), paediatrics (50%) and intensive care units (50%). Interventional radiology procedure was frequently performed by 30.8% of the participants as well as operating room support (7.7%).

Radiography projections used to study upper extremities

The shoulder is one of the main anatomical areas studied by conventional radiography with Neer projection referred as very frequent by 24/26 (92.3%) of the participants, followed by the antero-posterior (A/P) in the neutral position (21/26; 80.8%). The axial projection was also highlighted as very frequent by 15/26 (57.7%) of the radiographers, followed by the AP with medial and lateral rotations of the upper limb (46.2% and 42.3% respectively). Other projections that were used in clinical practice to study the shoulder were Zanca (23.1%) and AP Neutral for Surgical Measurements (15.4%). The West-Point view, Bloom-Obata, Bernageau, Lamy and Grashey were the less frequent projections performed in clinical practice (Figure 1).

Clavicle is mainly studied with AP projection (21/26; 80.8%) and/or AP with an inclination of the tube at 20° (19/26; 73.1%). The postero-anterior (P/A) projection is not required in the institutions that participated in this study.

The AP (14/26; 53.8%) and Rockwood (6/26; 23.1%) projections were identified as frequent to assess the acromioclavicular joint. The Axillar projection was not identified by the participants as an examination required.

The humerus typically was studied by using AP and Profile projections (17/26; 65.4%). The Oblique and Trans-thoracic views were not frequently required.

AP and Lateral (24/26; 92.3%) were the main projection highlighted to study the elbow. The oblique, tangential and olecranon views were referred as possible choices but not often performed. The forearm is frequently evaluated by using AP (18/26; 69.2%) and lateral (18/26; 69.2%) views, while oblique is not typically requested.

The wrist had 4 main projections identified as frequent: PA and lateral (24/26; 92.3%), as well as Schenck I (12/26; 46.2%) and II (10/26; 38.5%). Other projections identified by the participants to study the wrist were Kapanji (7/26; 26.9%) and oblique PA 45° in pronation (5/26; 19.2%). The carpal tunnel wrist view, oblique PA 75° in pronation, oblique PA 45° in supine were also referred (2/26; 7.7%) as well as Dupuy-Papillon and Monein views (1/26; 3.8%).

The hand bones had as very frequent option to be studied including the lateral (17/26; 65.4%), PA (15/26; 57.7%), AP (14/26; 53.8%), Oblique AP and PA (13/26; 50%) and bilateral PA (11/26; 42.3%) views; while the fingers were normally assessed by lateral (24/26; 92.3%), thumb (22/26; 84.6%), AP (16/26; 61.5%), PA (24/26; 50%) and oblique PA (7/26; 26.9%) projections.

The main clinical indications presented in the referrals by the physicians to require radiographies for upper limbs studies were mainly trauma, followed by degenerative and rheumatological disorders (Table 1). Oncological and congenital issues were rarely identified as reasons to perform plain radiographies to the upper limb area.

Radiography projections used to study lower extremities

Regarding the lower limb, participants identified it as the frequently requested radiography projections for pelvis, hip, femur, knee, tibia/fibula, ankle, foot, and toes (Figure 2). The main clinical reasons presented to perform these examinations are similar to those presented to the upper limb, namely trauma, degenerative and rheumatological disorders (Table 2).

For the pelvis region, the AP (24/26; 92.3%), AP for Surgical measurements (21/26; 80.8%), Lequesne (18/26; 69.2%), Lauenstein (15/26; 57.5%), Stitching (4/26; 15.4%), Lateral (2/26; 7.7%), AP Oblique Iliac (3/26; 11.5%), Inlet and Outlet views (1/26; 3.8%) were the projections identified as having still a role in diagnostic radiography. The pubic bones' view, Alar/Letournelle and Obturator views, sacroiliac joint's view are not performed in the participant institutions.

The hip examination was frequently performed by using AP (23/26; 88.5%) and Cross Table (16/26; 61.5%) views, as well as by the AP upright (6/26; 23.1%) and Frog Legs/Dunn (4/26; 15.4%) views. The femur radiographs were mainly executed

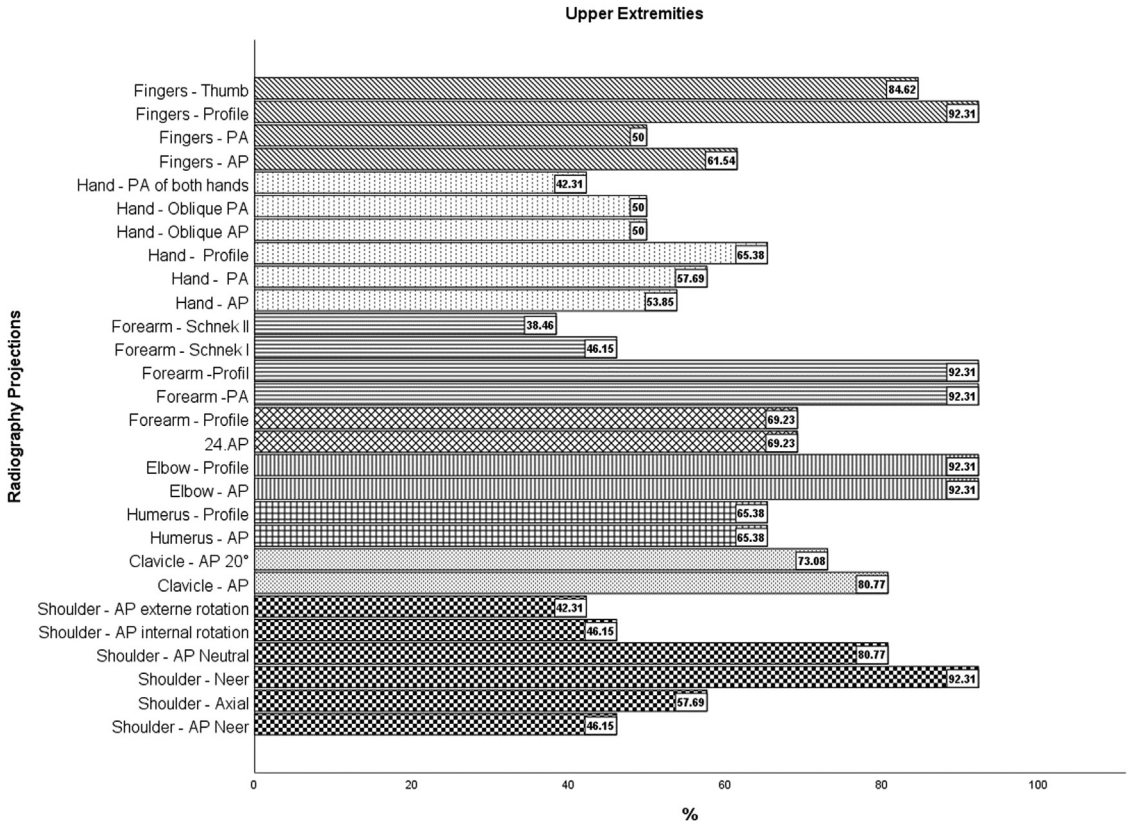

Figure 1. Distribution of the radiography projections most frequently asked to study Upper Extremities.

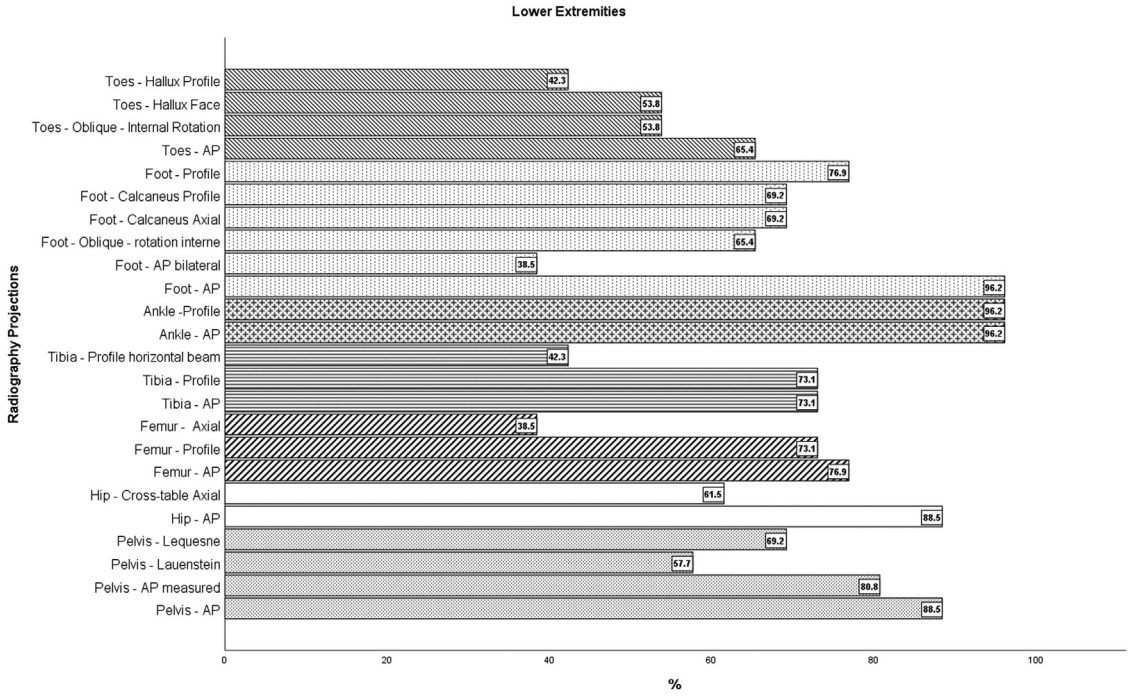

Figure 2. Distribution of the radiography projections most frequently asked to study Lower Extremities.

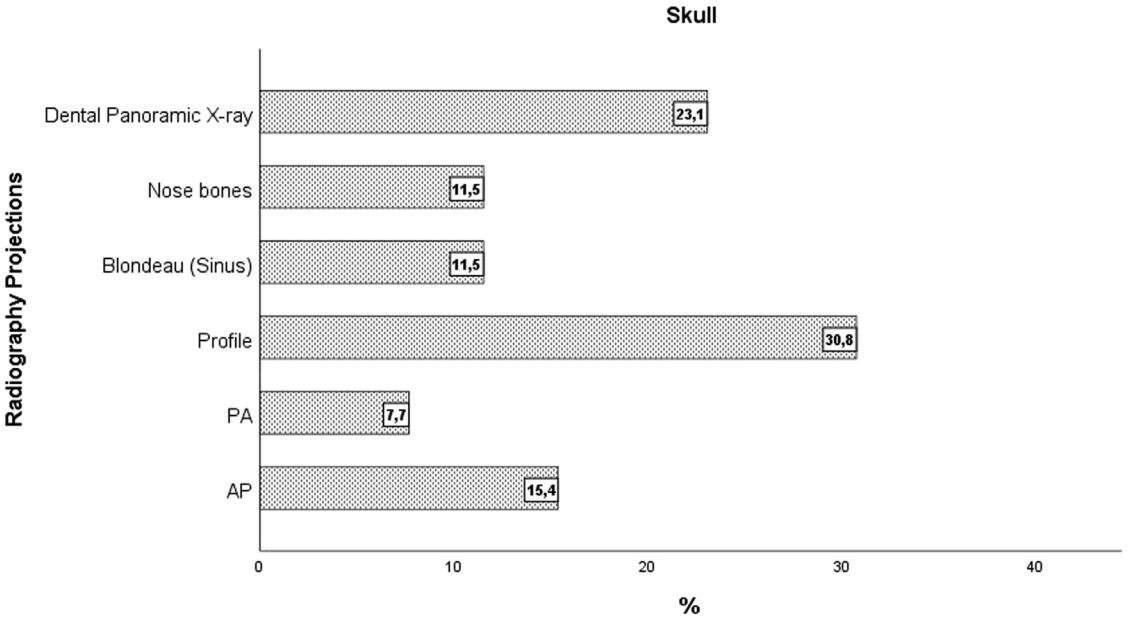

Figure 3. Distribution of the radiography projections most frequently asked to study the Skull.

Table 1
Main justifications by projection presented when plain radiography is required in clinical practice to study the upper limb region (shoulder, humerus, elbow, forearm, wrist, hand/fingers).

Upper Limb	Main Clinical Indications (Frequency ≥ 50%)		
Projections	Trauma	Rheumatology	Degenerative
Shoulder AP Neutral	87.5%	54.2%	54.2%
Shoulder AP Internal		62.5%	
Shoulder AP External		62.5%	
Shoulder Neer	91.7%		50%
Shoulder Axial	66.7%		
Shoulder Zanca	58.3%		
Clavicule AP	100%		
Clavicule AP20°	91.7%		
Humerus AP	100%		
Humerus LAT	100%		
Elbow AP	92.3%		
Forearm AP	92.3%		
Forearm LAT	92.3%		
Wrist PA	69.2%		53.8%
Wrist LAT	92.3%	69.2%	53.8%
Wrist Schrek	50%		
Hand/Fingers AP	75.0%		
Hand/Fingers PA	58.3%		
Hand/Fingers OBL	62.5%		
Fingers LAT	100%	58.3%	

Table 2
Main justifications by projection presented when plain radiography is required in clinical practice to study the lower limb region (pelvis, femur, hip, knee, tibia/fibula, ankle, foot).

Lower Limb	Main Clinical Indications (Frequency ≥ 50%)		
Projections	Trauma	Rheumatology	Degenerative
Pelvis AP	96.2%	53.8%	57.7%
Pelvis Lequesne	53.8%	57.7%	
Femur AP	88.5%		
Femur LAT	84.6%		
Tibia AP	76.9%		
Tibia LAT	76.9%		
Ankle AP	96.2%	57.7%	53.8%
Ankle LAT	96.2%	57.7%	53.8%
Foot LAT	92.3%		
Foot OBL	65.4%	50.0%	
Calcaneus Axial	88.5%		
Calcaneus LAT	84.6%		
Toes AP	76.9%		
Toes OBL	61.5%		
Toes/Hallux	50.0%		

in AP view (20/26; 76.9%), lateral (19/26; 73.1%) and Cross Table (10/26; 38.5%).

AP and lateral views (19/26; 73.1%) were also frequently used to study the tibia/fibula region as well as lateral with horizontal beam (11/26; 42.3%), while oblique view was never required. Similarly, for ankle studies, with AP and lateral view were referred as very regular examinations (25/26; 96.2%) by the participant radiographers.

The Oblique (7/26; 26.9%) and the AP Mortise were less frequently requested (1/26; 3.8%) and the radiographs for dynamic studies with dorsal and plantar flexions of the ankle were never performed in clinical practice in the participant institutions.

The feet, according to the participants, were studied by performing AP (25/26; 96.2%) and lateral (20/26; 76.9%) projections, specific views of calcaneus in Axial and lateral (18/26; 69.2%), mainly in trauma context or rheumatology disorders (Table 2). Oblique with medial rotation (17/26; 65.4%), AP bilateral (10/26; 38.5%), AP with perpendicular beam (4/26; 15.4%), Meary view (2/26; 7.7%), Anthonsen view (1/26;

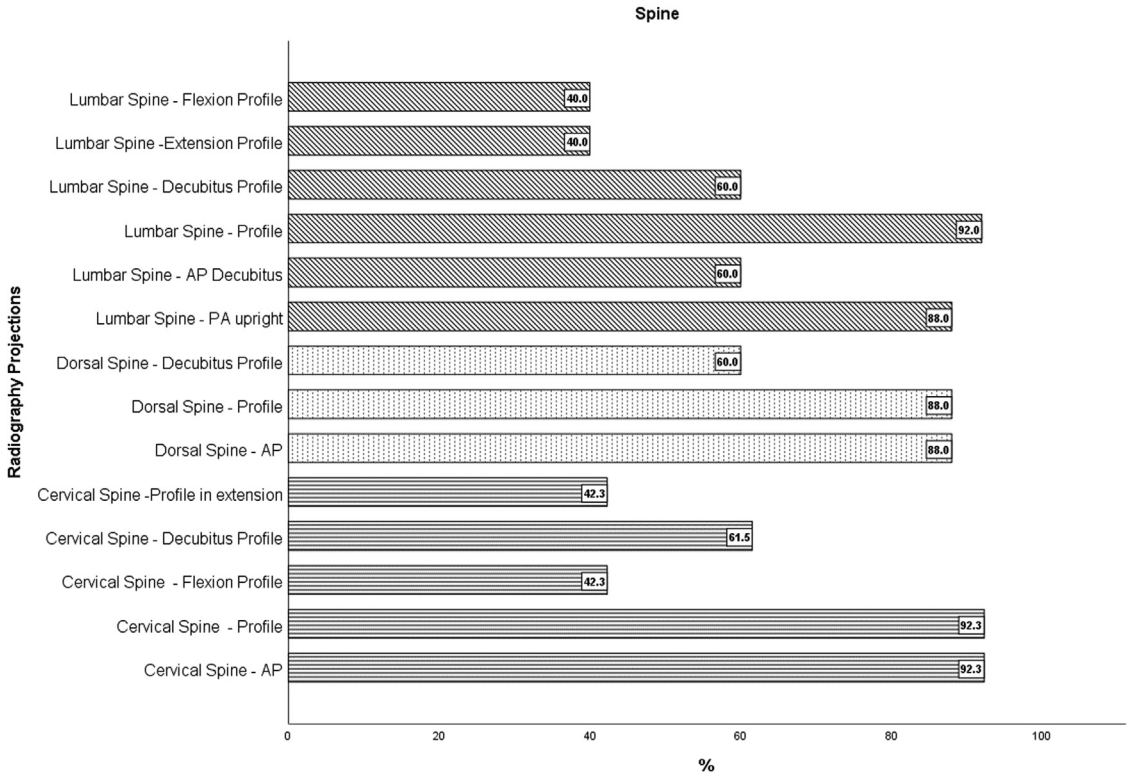

Figure 4. Distribution of the radiography projections most frequently asked to study Spine.

3.8%) were also identified as demanded. The Guntz view for ankle was not required in the clinical practice.

The AP view (17/26; 65.4%), Oblique (14/26; 53.8%), Lateral (10/26; 38.5%) and AP with cranial angulation of the beam (2/26; 7.7%) were the main projections identified to study the toes with radiographs. The Oblique with lateral rotation or the projection specific for sesamoid studies were never required; while the Hallux were typically assessed by doing AP (14/26; 53.8%) and Lateral views (11/26; 42.3%).

Radiography projections used to study skull and spine

Results showed that skull is not being imaged very often by using plain radiography. Four out of ten proposed projections were not performed at all in Western Switzerland Medical Imaging departments, namely Hirtz, Tangential Nose Bones, Worms and Caldwell's views. The Lateral view (8/26; 30.8%) is still required, as well as panoramic scanning dental X-ray (6/26; 23.1%), AP (4/26; 15.4%), Blondeau, Lateral Nose Bones (3/26; 11.5%) and PA view (2/26; 7.7%) (Figure 3) due to trauma (40%), oncological follow up (24%), congenital issues (24%), degenerative (8%) and rheumatological disorders (8%).

Regarding spine studies (Figure 4), cervical the AP and Lateral views were identified as frequently requested examinations (24/26; 92.3%) by participant radiographers, followed by Odontoid studies (20/26; 76.9%), Lateral with patient in decubitus (horizontal beam) (16/26; 61.5%), Dynamic studies/flexion and extension (11/26; 42.3%) and Oblique views (7/26; 26.9%).

AP, Lateral (22/26; 88%) and Lateral with patient in decubitus (horizontal beam) (15/26; 60%) were the projections highlighted as relevant to examine the thoracic spine, while Oblique views were referred as not performed.

The lumbar spine, according to the participants, is typically assessed in clinical practice by 10 different projections, with Lateral (23/26; 88.5%) and PA upright (22/26; 84.6%) views as the most frequently requested. The AP with the patient in decubitus and Lateral in decubitus (15/26; 57.7%) were also referred, followed by Lateral Dynamic studies (Flexion and Extension) (10/26; 38.5%), AP upright (5/26; 19.2%); PA with the patient in decubitus (5/26; 19.23%). The Oblique and Bending views were the less frequent in their practice (1/26; 3.8%).

Lateral (8/26; 30.8%), AP (7/26; 26.9%) and Barsony (6/26; 23.1%) were the projection identified to study the sacrum. The PA view was not requested and for the coccyx just AP (5/26; 19.23%) and lateral (7/26; 26.9%) were identified as required.

The clinical indications presented to study the spine by radiography were trauma (88.5% /92% / 80%), degenerative (64% / 64% / 40%) and rheumatological disorders (60% / 60% / 68%) for cervical, dorsal, and lumbar spine respectively.

Radiography projections used to study thorax and abdomen

To study lungs, the PA, lateral (23/26; 88.5%) and AP (19/26; 73.1%) views were referred as frequently required in clinical practice, while Lordotic view is not performed. The main justifications presented by the practitioners to request

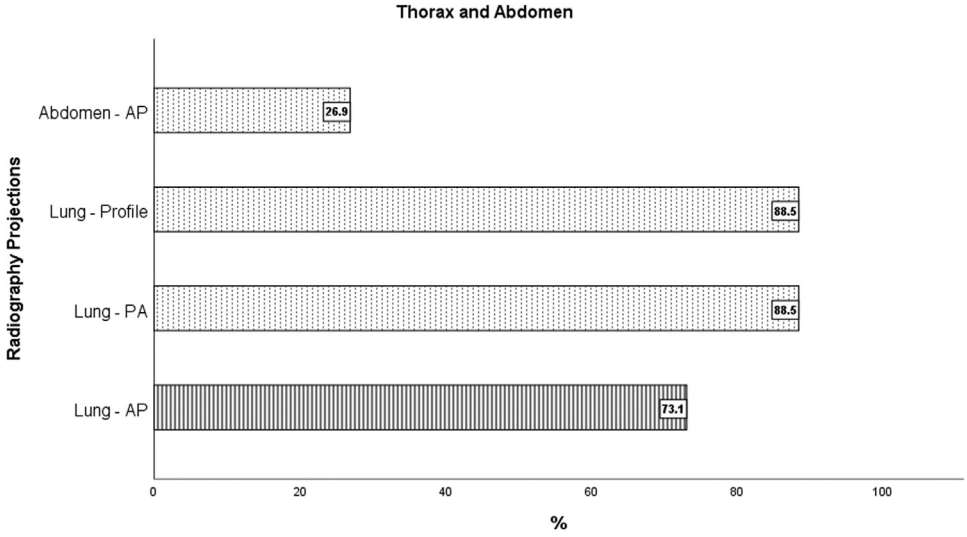

Figure 5. Distribution of the radiography projections most frequently asked to study Thorax and Abdomen.

a radiography are infections (57.7%), pain (50%), dyspnoea (50%), oncological follow up (65.4%), follow up in intensive care (61.5%) and screening (76.9%).

Regarding the costal grid, the oblique view was identified as performed (4/26; 15.4%), as well as PA view (3/26; 11.5%) (Figure 5).

The abdomen AP in decubitus was highlighted as very frequently demanded studies (20/26; 76.9%), followed by abdomen AP upright (8/26; 30.8%) and PA (7/26; 26.9%). The lateral view and the decubitus tangential were also required in clinical practice but as less frequent (2/26; 7.7%).

The few abdominal radiographies performed in clinical practice are due to the need of exploring if the catheters are well placed (73.1%), the presence of foreign objects (61.5%) and occlusions (61.5%).

Significant differences were identified between public and private institutions practices in terms of frequency with a relatively strong association for the Cervical Spine Lateral view with patient in decubitus (horizontal beam) *($p = 0.001$) (Cramer's $V = 0.675$),* Lumbar Spine AP *($p = 0.002$) (Cramer's $V = 0.667$)* and Lumbar Spine lateral view *($p = 0.002$) (Cramer's $V = 0.667$)* with patient in decubitus, Femur Cross-table axial *($p = 0.003$) (Cramer's $V = 0.625$).* With a moderate association the following examinations were identified: Tibia-Fibula AP *($p = 0.005$) (Cramer's $V = 0.590$)*, Tibia-Fibula lateral view *($p = 0.005$) (Cramer's $V = 0.590$),* Femur Lateral view *($p = 0.005$) (Cramer's $V = 0.590$),* Neer AP *($p = 0.005$) (Cramer's $V = 0.573$)*, Tibia-Fibula horizontal *($p = 0.014$) (Cramer's $V = 0.517$)*, Femur AP *($p = 0.018$) (Cramer's $V = 0.505$)*, Thoracic Spine Lateral view with patient in decubitus *($p = 0.034$) (Cramer's $V = 0.500$)* and Blondeau PNS ($p = 0.046$) (Cramer's $V = 0.457$).

Discussion

The use of medical imaging examinations that require exposure to ionising radiation needs to be medically justified [27]. Justification can avoid unnecessary radiation exposure, when the appropriateness of the examination is really taken into account and the benefit of performing it overcomes the potential risk. However, the criteria used in the decision-making process, which resulted from consensus and research, are not yet fully disseminated as they are adopted only in some countries [28–30]. and that can cause overuse of imaging, resulting in additional risks and costs in healthcare [15]. The accessibility to healthcare services namely to cross-sectional imaging (CT, MRI, PET-CT) in Switzerland is also an aspect that cannot be neglected, and it may explain as well the decrease on the use of plain radiography [31]. The lack of education and training about the ability of each radiological examination to answer a specific medical question can be one of the other reasons behind the "no justification" or inadequate justification of examinations [19,32].

In Switzerland, as referred before, CT examinations are increasingly used [9] with plain radiography as a second choice or even being replaced by CT. The limitations of plain radiography including superimposition of structures are solved by cross-sectional imaging modalities thus allowing a more detailed analysis of relevant anatomy, even having most of the times higher dose levels [9,33]. The skull/brain, spine and abdomen are anatomical areas that can beneficiate the add-value of sectional imaging. Plain radiography can be used to image the skull, but the frequency identified in this study is lower compared to the other anatomical regions, which is within expectation since plain radiography has no added value over CT scan mainly to assess intracranial injuries [21,34]. For the spine, in Swiss context, radiography is being used in trauma and degenerative contexts for non-complex situations due to its capacity to answer the medical questions, but reach its limitations for inflammations, tumors and unstable traumatism, giving place also to CT or MRI examinations [20,35].

Abdominal radiographs are still performed as well in Swiss practice to evaluate catheters positioning (73.1%), the presence of foreign objects (61.5%) and occlusions (61.5%), which is

aligned with other studies [22,36,37]. However, abdominal radiographs have limitations for liver diseases (metastasis, hepatocellular carcinoma, and liver abscess without air), pancreatic diseases, ischaemia and infectious/inflammatory diseases even when presenting patterns that can lead to the diagnosis [36].

This study showed that chest radiographs are still frequently performed for infections (57.7%), pain (50%), dyspnoea (50%), oncological follow up (65.4%), follow up of intensive care cases (61.5%) and screening (76.9%). Other references [5,38]. indicate this examination as useful for pre-operative evaluation, initial examination in trauma context and acute respiratory illness. When heart failure is suspected [17]. the chest radiographies present evidence of congestion, which can guide the physicians to predict prognosis and patient follow up. It can reduce the referrals as well to a medical specialist or it can guide to better adapt medicine prescription and it can give reassurance to the patient [18].

According to the results of this study, the main role of plain radiography in Western Switzerland is to assess appendicular skeletal (upper and lower limbs). The assessment of acute skeletal trauma, with the exception of more complex spine trauma is one of the justifications that aligns with literature [39]. The study of bone lesions by providing differential diagnosis of skeletal tumors and tumour-like lesions [40] is another area that plain radiographs is able to provide information. Even having plain radiography being barely used to assess and follow bone metastases in the participant institutions, some studies [23,24]. showed that is possible since it has a sensitivity of 71.4% and an accuracy of 50% [23]. However, the training and experience in interpreting the examinations is critical [24] to identify the lesions.

Some differences on practice were observed between public and private institutions, namely regarding the type of projections that are being performed and this may be related to the available resources and professional experience or preferences.

The main limitation of this study is related to the geographical area covered, having only the French part included and not the German or the Italian. Radiographers' profession, education and training, roles, competences and activities vary between the 3 parts being possible that the other parts of the country have a different reality. In addition, due to the data collection overlapping with the second national lockdown in Switzerland, and due to the radiographers working on the frontline during this period, the recruitment was inevitably impacted. These limitations could be addressed in future studies.

Conclusions

Plain radiology has a role to play in Western Switzerland mainly for skeletal evaluations of upper and lower limbs, especially the shoulder, in trauma, degenerative and rheumatological disorders. Skull radiographs are not widely used. Chest, abdominal and spine are also being explored with plain radiography studies under some contexts and knowing that the training of healthcare professionals should be implemented to justify, perform and interpret adequality the examinations to take advantage of all information that can be provided. Radiographs' information can provide support and guidance to the practitioners to manage the patients in a more personalized approach with judicious use of available resources while avoid unnecessary imaging examinations.

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