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Ethical Consideration When using X-ray Examination for None Medical Purposes

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Abstract: ***Forensic Age assessment is a branch of forensic medicine which aims to describe in the most precise method, the chronological age of a person of unknown age. The process of age estimation is very essential in solving problems such as individuals of doubtful age involved in medical or legal proceedings, this includes unregistered children, asylum seekers, immigrants, marriage, sporting events and criminals. Currently, many researchers have relied on the radiographic method of assessing the chronological changes in bone development as a reliable tool in the estimation of age of living subjects. However, little work has been done to assess ethical aspects of exposing children to this examination and the effects of radiation for such none diagnostic procedures.***

Keywords: Radiation, Ossification, Ethics, Clavicle

1. Introduction

Before considering the benefits of age assessment using radiological methods, it is important to first consider the context within which age assessments take place and any ethical issues with which they are associated. Of course, the ethical issues raised by age assessment and the methods employed cannot be separated from the framework of principles of medical ethics.

Bioethics, a branch of moral philosophy, comprises four guiding principles: respect for autonomy, beneficence, non-maleficence and the principle of justice (UNICEF, 2012). These principles may be accorded varying weight and the appropriate application of the values will be subjective in any given clinical situation. However, the principles can serve as tools to assist in the handling of the situation, the reaching of any decision and subsequent analyses of decisions previously made.

2. Radiation Exposure for Non-Medical Purpose

The radiation exposure for non-medical purpose gives rise to important ethical issues as noted in a recent publication regarding age assessment of individuals subject to immigration control in the United Kingdom(Aynsley *et al.*, 2012), which affirmed that it is necessary to weigh up the actual benefits with the potential damage that might be caused to a group of children and young people who are potentially vulnerable as a consequence not only of their age but also their background and experiences (Aynsley *et al.*, 2012). In this regard, there is no doubt that the amount of radiation exposure involved in chest X-rays is negligibly low.

But even at this low-dose level, statistically significant increases in cancer rates have been observed (Sodickson *et al.*, 2009), and the difficulty in obtaining such reliable data of cancer rates is due to one decisive reason: most radiation induced cancers, have a latency period of more than 40 years between exposure and the appearance of the disease.

While this may be true, a number of new studies have also been published about the special cancer risk that children may suffer from diagnostic X-rays in recent years (Adelstein, 2014). Children and adolescents who constitute many of the cases in forensic age estimation proceedings are considerably more sensitive to the carcinogenic risks of ionizing radiation than adults. As a result, the International Commission on Radiological Protection (ICRP) approved new recommendations for the protection against ionizing radiation in 2007, which take into account biological and medical information of the patients exposed to radiation (Christner *et al.*, 2010).

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) states that the radiation exposure associated with chest and wrist X-rays is minimal and that there is wide acceptance in the scientific community that the radiation dosage from a chest X-ray poses negligible risks to a person's health (ARPANSA 2013). ARPANSA estimates that a standard X-ray examination of the proximal epiphyses of the clavicle is 0.1 microSievert (μSv), while that of CT ranges between 600 to 800 μSv (microSievert). This makes the radiation exposure through conventional X-ray very low as compared to other medical procedures (Table 11), X-ray examination of the hands is 0.1 microSievert (μSv), and in case of Orthopantomograms 220 μSv while the effective dose in case of a complete thorax TC is 6.6 mSv(Ramsthaler *et al.*, 2009).

When the above doses are compared to the categories of risk and the corresponding levels of benefit to society expected from the radiation exposure (Table 1), it is clear that this exposure rates are of minimal risks as shown in table 1, which has been modified from that published by the ICRP (ICRP, 2007) and incorporates the risk terminology recommended by Calman(1996).The Sievert (symbol: Sv) is a derived unit of ionizing radiation dose in the International System of Units (SI). It is a measure of the health effect of low levels of radiation on the human body (1000 μSv=1mSv). Quantities that are measured in Sieverts are intended to represent the stochastic health risk, which for radiation dose assessment is defined as the probability of cancer induction and genetic damage.

Table 1: Categories of risk, corresponding levels of dose and corresponding levels of benefit to society (Einstein et al., 2007)

NO	*Level of risk*	*Risk category*	*Effective dose range (mSv) in adults*	*Level of societal benefit expected*
1	Minimal	Category I (10^{-5} or less)	< 0.2	Minor
2	Very low	Category II a (10^{-5} to 10^{-4})	≥ 0.2	Intermediate
3	Low	Category 11b (10^{-4} to 10^{-3})	≥ 2 and ≤ 20	Moderate
4	Moderate	Category III (10^{-3} or more)	> 20[1]	Substantial
Note: This risk levels represent very small additions to the 1 in 5 chance we all have in dying of cancer				

3. Is there a safe dose of radiation?

Schmeling *et al.* (2011) argue that whilst there is some degree of exposure to ionizing radiation linked to any radiographic process, but when radiographs are taken for age estimation the doses involved are 'within acceptable limits' in relation to naturally occurring environmental radiation exposure. According to the United Nations Scientific Committee on the effects of atomic radiation and the International Commission on Radiological Protection (ICRP), the exposure to radiation of the populations in western countries has continually increased in the past decades (Morgan and Bair, 2013), these increase has been calculated as an average in Africa at 0.85 mSv/y, Germanyatabout1.2mSvper year and in the Netherlands at about2.0mSv (Morgan and Bair, 2013).

The average dose of radiation from a single radiograph in the UK is 0.01 mSv, while the average annual radiation exposure in the UK per year is 2.7mSv (Allison, 2009). Chest X-ray is therefore equivalent to approximately 25 minutes of exposure to naturally occurring radiation. However any exposure to radiation is not without risk and the use of X-rays and their potential for harm remains controversial (Allison, 2009; Walker, 2000).

But because of high radiation dose, the use of CT is restricted to answering the question of whether an individual has completed the 18th or 21st. A CT of the sternoclavicular joint produces a dose of approximately 600–800 µSv per examination (Bromberg and Covarrubias, 2012), accounting for a disproportionately higher radiation dose than other diagnostic X-ray methods. However, surveys have shown that the radiation exposure specifically from CT depends heavily on the parameter settings.

4. Radiation Risks

To date, many risk estimations for X-rays are based on the linear no-threshold model (LNT) which states that the extrapolation of radiation-induced health risks from observed high to low doses is strongly linear and that this effect is valid even down to zero doses (Martin, 2014), therefore it (LNT) assumes that the long term, biological damage caused by ionizing radiation (essentially the cancer risk) is directly proportional to the dose.

Martin (2014)reviewed the evidence for and against the LNT hypothesis and explained that, at present, the scientific community favours the LNT philosophy as the most evident risk model. However, data from patients who underwent numerous-ray examinations during their childhood because they were suffering from tuberculosis or scoliosis demonstrate a significant increase in cancer incidences in their future life (Cohen *et al.*, 2012).

Nevertheless, the possible cancer risks due to ionizing radiation from X-ray doses below 1 mSv (Millisievert) are still too small to be calculated directly from epidemiological data, and this is the case for nearly all methods used in forensic age estimation (Schmeling *et al.*, 2008). For clear comparison, the radiation doses from commonly used radiographs and the age-related risk estimates are shown in table 11

Some authors have stressed the insignificance of the usual FAE examination doses in comparison with naturally-occurring and civilizing radiation exposure and even other diagnostic procedures (Table 11).Flight staff of airplanes receive an average of 0,008mSv per hour of radiation exposure from intercontinental flight at an altitude of12000meters, translated to 2000mSv per year as a result of staying high in air (cosmic radiation), this is considered a moderate level of risk by the ICRP (Table 11), but the benefits of air travel is considered substantial in a civilize world(Schmeling *et al.*, 2008).

It also follows that the radiation dose effective in case of an intercontinental flight is equivalent to a CT of sternoclavicular joints is equivalentto3.5months of naturally occurring radiation exposure. On the basis of these comparisons the health risk as a result of usual X-ray examinations for forensic age determination (FAE) is negligible (Schmeling *et al.*, 2008). Nevertheless, radiation exposure produce not only stochastic (Random) but non-stochastic damages the physicians must be aware of. Non-stochastic effects appear above 100 mSv and are thereforeirrelevantinusualradiologicaldiagnosis.Butnon-stochasticeffectsdon't have such a threshold and are not dose related, so their eventual appearance in case of X-rays examinations must be cautiously considered. Some authors minimize and other maximize the harm inherent to these non-stochastic effects (Garamendi *et al.*, 2011).

Table 1: Approximate dose and cancer risk of various radiation sources

Radiation source/ Procedure	Radiation dose in	Equivalent period of natural background radiation	Additional lifetime risk of fatal cancer
FLIGHT:			
Airport security X-ray scanner	0.00001 mSv	Less than 1 year	Negligible
7 hours air plane flight	0.003 mSv	A few days	Negligible
HEART:			
Coronary Angiography (CTA)	12 mSv	4 years	Low
Cardiac CT for Calcium Scoring	3mSv	1 year	Low
CHEST :			
Radiography-Chest	0.1 mSv	10 days	Minimal
Computed Tomography-Chest Low Dose	1.5 mSv	6 months	Very Low
DENTAL:			
Intraoral X-ray	0.005 mSv	1 day	Negligible
ABDOMINAL REGION:			
(CT)-Abdomen and Pelvis	10 mSv	3 years	Low
(CT)-Colonography	10 mSv	3 years	Low
X-ray -Lower GI Tract	8 mSv	3 years	Low
Radiography (X-ray)-Upper GI Tract	6 mSv	2 years	Low
BONE:			
Radiography (X-ray)-Spine	1.5 mSv	6 months	Very Low
Radiography (X-ray)-Extremity	0.001 mSv	3 hours	Negligible
CENTRAL NERVOUS SYSTEM:			
(CT)-Head	2 mSv	8 months	Very Low
Computed Tomography (CT)-Spine	6 mSv	2 years	Low

5. Trials of Radiation Free Techniques in the Field of Age Estimation

Due to the restrictions imposed by the German X-ray ordinance, the use of radiological examinations without medical indication is not permitted in almost all situations, except in the cases (criminal proceedings) provided by law for this purpose (Schulz *et al.*, 2008). As a result of which, the accuracy level of age estimation procedures for civil and asylum proceedings has been reduced. Thus, the attention of the modern group of scientists has been drawn to employ radiation-free bone assessment techniques in this context. Only conventional radiology and Computed Tomography were used successfully to study the ossification stages of medial clavicular epiphysis till 2006.

Schmidt *et al.* (2013a)carried out a study on Magnetic Resonance Imaging (MRI) of sternoclavicular joints with the aim to prove, whether the degree of ossification of epiphyseal cartilage could be assessed on MRI scans, this was the first attempt to their knowledge to study clavicular ossification using MRI but he studied only 56 cadavers. His team (Schmidt *et al.*, 2013b) recommended that the achieved results should be examined with a large number of cases, and a modified protocol of MRI examination is required for the examination of the medial clavicular epiphyseal cartilage for the purpose of forensic age diagnostics of living individuals.

It is also important to note that MRI is a very expensive making it less accessible, it also requires more expertise as compared to the conventional digital X-rays. Hillewig(2011) also noticed that differentiation between stages 4 and 5 when using MRI appeared to be impossible as the epiphyseal scar was never visible (stage 4) on the MRI images (Figure 27), this was because of the low sensitivity for the very thin calcified scar. In the literature, stage 4 was first observed on radiographs at the age of 26 which is not within the age range of 14–22 that is most frequently used in age estimation cases (Schmeling *et al.*, 2004). In cases where the age threshold of 21 is important, identification of stage 5 is of no consequence and this technique is therefore of little or no benefit in these cases. Although the visualization of the epiphyseal scar can be important in cases where age needs to be established, e.g. several years after a crime has been committed, it is not a crucial parameter in most age estimation cases

A year later, Schulz *et al.*(2008) carried out an ultrasound study on the time course of clavicular ossification for forensic age estimation in the living subjects above 18 years of age. The study was conducted to establish a radiation-free imaging technique, using a Pro Focus 2202 Ultrasound System (B-K Medical, Herlev, Denmark) equipped with an 8MHz linear transducer and a standoff pad. The right clavicles of 84 test subjects, aged between 12-30 years were evaluated, prospectively by ultrasonography. Ossification stage evaluation was possible and were found to be consistent and comparable to the known data of CT assessment.

The authors suggested for confirming the results of their study in larger sample size and with analysis of observer variability. Evaluation of medial clavicular epiphyseal ossification by ultrasound could ultimately be a rapid and non-ionizing economic diagnostic modality for forensic age estimation.

Apart from being a radiation free technique, sonography has additional advantages of being economical and fast, easy to use and can be applied as a mobile unit. But a major drawback to its application in forensic age diagnostics is that to date, insufficient number of cases has been investigated using this technique, and it has lower resolution as compared to CT, X-ray or MRI

Since sonography is a dynamic examination procedure, it has difficulty in adequately documenting findings in still images, this is shown by the fuzzy/ cloudy image above. Furthermore, unlike MDCT, MRI and convectional X-rays, the sound waves cannot easily pass through the bone to show inner structures (Schulz *et al.*, 2008).

6. Conclusion

Since a complete elimination of all risks in these techniques is not possible, the question arises what type and degree of risk the society is willing to bear. Hall has claimed that a risk of harm of one in a million should be generally ignored (Schmidt *et al.*, 2007). On the basis of general and unrestricted life risks (i.e., pregnant women use air crafts as a means of transportation), procedures applied that can pose comparable risks, for example, through the X-ray exposure of the clavicle, should be considered justifiable. In view of the significantly higher radiation doses through the use of CTs, it is particularly advisable and, indeed, necessary to adhere to the diagnostic reference values (DRV).

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