Optimizing landmark selection in head CT: impact on eye radiation dose and diagnostic quality

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Abstract. Head CT is the most frequent examination in every hospital in Indonesia. Radiation protection on Head CT is important because of the existence of sensitive organ that is eyes.The present study investigated the impact of different cranial baselines on image quality and lens radiation dose in head CT. Diagnostic information was evaluated in six cases, three scanned using the OML and three with the SOML baseline, and subsequently reviewed by three radiologists through a structured questionnaire. Ocular radiation dose was measured in ten additional cases, five per variation, using TLD-100 dosimeters placed on the eyelid. Measured values were compared with the reference provided in ICRP Publication 87 (2000). The findings showed no significant difference in image information between the SOML and OML orientations, as indicated by the T-test result with a p-value of 0.7419. A substantial reduction in radiation dose was observed when using the SOML baseline (6.411–8.747 mGy) compared with the OML baseline (50.729–70.952 mGy). For head CT examinations, it is recommended that the scanogram be aligned parallel to the SOML, as this orientation provides greater protection for the eyes.

1 Introduction

The use of CT examinations has continued to increase due to their ability to provide rapid diagnostic information, particularly in emergency situations, even though they account for only 9% of radiological procedures while contributing nearly 50% of total diagnostic radiation exposure [1]. International survey data indicate that Japan has the highest annual diagnostic imaging utilization and the greatest associated risk, with diagnostic radiology linked to an estimated cumulative cancer risk of 3.2% [2]. The crystalline lens, composed of a single layer of metabolically active epithelial cells, is highly sensitive to ionizing radiation, and damage to these cells can result in lens opacity and cataract formation. Although earlier assumptions placed the cataractogenesis threshold near 2,000 mGy, recent evidence suggests a substantially lower threshold of about 500 mGy—or potentially no threshold at all—indicating that radiation-induced cataract formation may be stochastic in nature [3].

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CT imaging systems are generally categorized as either single-slice or multi-slice scanners, the latter often referred to as Multi-Slice CT (MSCT). As highlighted by Bontrager [4] MSCT provides several advantages compared with single-slice technology, including shorter scanning times, reduced exposure duration, and enhanced image quality. Accurate interpretation in cranial CT examinations requires high-resolution images to clearly depict pathological changes. Cranial CT is the primary imaging modality for evaluating neurological conditions such as traumatic injury, ischemic events, hemorrhage, and elevated intracranial pressure, accounting for 30–80% of CT examinations overall [5]. Gantry orientation is typically guided by anatomical landmarks, namely the Orbitomeatal Line (OML), Supraorbitomeatal Line (SOML), and Infraorbitomeatal Line (IOML) [6].

Different researchers have proposed varying recommendations for establishing the cranial baseline. Wijokongko [7] and Caryn Damits [8] advocate positioning the baseline above the OML or parallel to the SOML, extending toward the cranial base. Conversely, Jones [9] and Y.I Kim [10] recommend aligning directly along the OML, whereas Bontrager [4] suggests using the IOML as the reference, likewise extending to the cranial base.

Such differences in baseline selection inevitably lead to variations in cranial cross-sectional images. Since the crystalline lens is one of the most radiosensitive organs, baseline alignment should also consider minimizing ocular radiation exposure. Consequently, comparative investigation between SOML- and OML-based protocols is necessary to identify the most appropriate diagnostic approach that balances image quality with radiation safety. The present study therefore aims to evaluate the differences in diagnostic performance and ocular radiation dose between these two methods, ultimately contributing to the development of optimized head CT protocols with reduced lens exposure.

2 Methods

2.1 Study design

This study employed an comparative quasi-experimental study incorporating both data collection and quantitative analysis. Utilizing two cranial landmarks—OML and SOML—as illustrated in Fig.1. Evaluation of diagnostic information was conducted on six patients undergoing cranial CT, with three patients analyzed for each landmark variation. The sample of this study must fulfill the requirements of the inclusion criteria, include: 1) aged around 20-70 years, 2) the sample has a head diameter of 17 cm, 3) the sample is willing to undergo examination and follow the course of the study. The sample did not include pregnant women patients.

To maintain comparability in image quality and to reduce potential bias, all CT acquisition parameters were standardized. Measurement of ocular radiation dose was performed in ten additional patients, with five allocated to each of the two landmark groups.

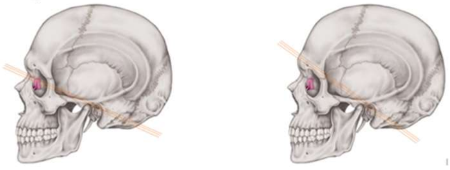
(a) (b)

Fig. 1. (a) Landmark OML; (b) Landmark SOML [6]

2.2 Image data acquisition

This study utilized a Hitachi 16-slice CT scanner and its monitor console as the primary equipment. Images were obtained using cranial baseline landmarks set at OML and SOML. Prior to scanning, all identifying information was anonymized to ensure subject confidentiality. The imaging protocol employed the following parameters shown in Table 1.

Using window width (WW) of 150 for brain and 1500 for bone, and window level (WL) of 50 for brain and 250 for bone. After image acquisition, data were reconstructed using the Multi-Planar Reconstruction (MPR) technique. From each dataset, axial sections were produced according to the three reference baselines.

Table 1. Acquisition parameter for CT brain

Protocol	Tube Potential	Tube Current	Time	Slice Thickness
CT Brain	120 kVp	300 mA	0,5 s	0,5 mm

Image assessment was carried out using questionnaires completed by three radiology experts, who reviewed axial sections generated from each baseline protocol. The questionnaire focused on two criteria: anatomical visualization and artifact presence. Anatomical clarity was scored on a three-point scale (1 = unclear, 2 = moderately clear, 3 = clear), whereas artifacts were evaluated dichotomously as either present or absent for each cranial baseline.

2.3 Dose measurement

For ocular dose estimation, Thermoluminescent Dosimeter (TLD) chips were positioned on one eyelid of patients during cranial CT scanning. The examinations were carried out using a Hitachi Elcos 16 CT system with ten sets of TLD-100 LiF:Mg,Ti dosimeters.

The study procedure was conducted as follows:

- Informed consent was obtained, after which a TLD chip was positioned on the patient's eyelid to record radiation dose
- Patients were placed supine on the CT couch.
- For the first five patients, the scanogram was aligned parallel to the OML and SOML

The formula for the absorbed radiation dose (D) for photon radiation (X-rays) at a distance r can be expressed by the following equation:

$$D(r) = \frac{I_0 t}{r^2} e^{-\mu x} \frac{\mu_{en}}{\rho} \qquad (1)$$

Where I_0 = initial intensity of the source (J/s), t = exposure time (s), r = distance between the source and the tissue (m), μ = linear attenuation coefficient (cm^{-1}), x = thickness of the material traversed (cm), μ_{en} = mass energy-absorption coefficient (m^2/kg), dan ρ = mass density of the tissue (kg/m^3).

From the equation above, it is known that the dose is inversely proportional to the square of the distance ($D \approx \frac{1}{r^2}$), so the farther the distance between the source and the tissue, the smaller the absorbed radiation dose received by the tissue. Similarly, in this case, for OML the radiation source is closer to the eye tissue because it is in a parallel position, whereas in SOML the source and the eye tissue are not aligned. This causes the radiation dose received by the eye to be greater in OML compared to SOML.

2.4 Data analysis

Statistical data analysis for diagnostic information was performed using Python within the open-source platform Google Colab. An independent-samples T-test was applied to compare diagnostic information between the two landmark variations, with a ρ-value of <0.05 considered statistically significant.

Radiation dose data were processed using descriptive statistical methods and subsequently compared with the reference values provided in ICRP Publication 87 (2000). The analyzed results were then used to draw conclusions and to formulate recommendations regarding the acceptability of radiation doses. The processed results of diagnostic information and radiation dose were subsequently discussed and compared with theoretical references.

3 Results and discussions

3.1 Diagnostic quality

The Independent T-test is shown in Table 3 with the ρ-value is 0,7419, indicating that there is no difference in image information between the CT Head examination using the SOML and OML baseline landmark variations. Diagnostic information related to artifacts is presented in Table 2, which demonstrates that no artifacts were observed in head CT images acquired using the OML and SOML baseline landmarks. This finding indicates that the application of these two landmarks does not generate artifacts.

Table 2. Results of artifact assessment on variations in head CT landmarks

Image Information	OML	SOML
Artifact	None	None

Table 3. Independent T-Test

Image Information	T-statistics	p-value
Anatomy Information	0,3358	0,7419

Three main perspectives exist regarding the reconstruction of axial sections in cranial CT examinations. Studies by [9] and [10], suggest that axial orientation should be aligned either above the orbitomeatal line (OML) or parallel to the supraorbitomeatal line (SOML), extending toward the cranial base. According to Dr. Jeremy Jones [11] employing the SOML as a reference line may help to reduce artifacts generated by dental restorations projected into the posterior fossa. Thus, the findings indicate that there is no difference in image quality between the SOML and OML orientations; however, when considering radiation dose, the SOML is preferable for use.

3.2 Radiation Dose to the lens

The measurement outcomes are summarized in Table 4 reveal variations in the radiation dose despite the use of identical exposure factors. The maximum ocular dose recorded was 70.952 mGy used landmark parallel to the OML, whereas the minimum dose was 6.411 mGy utilizing a line originating from the SOML.

Table 4. Comparison of radiation dose measurement result and ICRP guidance Number 87 of 2000

Landmark	Radiation Dose (mGy)	ICRP guidance of Number 87 of 2000	Notes
OML	53,889	50 mGy	exceed 8%
	50,729		exceed 1,4 %
	60,407		exceed 21 %
	45,935		safe
	70,952		exceed 41 %
SOML	7,265		safe
	6,944		safe
	7,239		safe
	8,747		safe
	7,265		safe

Efforts to reduce radiation exposure to the eyes during head CT scans often involve adjusting the scanogram so that the initial line is aligned parallel to the SOML, thereby avoiding direct irradiation of the ocular structures. Research has shown that proper head positioning combined with gantry angulation toward the SOML can substantially decrease lens dose, with reductions reported between 46% and 90% [11-12]. Tilting the gantry is a simple and cost-effective method that allows the eyes to be placed outside the primary radiation field. European guidelines support this approach by recommending a 10–20° tilt above the orbitomeatal line to further minimize radiation to the eye lens [13].

When properly executed by radiologic technologists, these techniques can be highly effective; however, they are often underutilized due to limited awareness of dose-optimization procedures. Findings from previous research emphasize that comprehensive staff training is essential for achieving significant reductions in patient radiation exposure [14]. Radiographers, physicists, and radiologists must work collaboratively to select and adjust optimal parameters and scanning protocols in order to minimize the absorbed dose for each patient [15].

Therefore, the selection of the SOML as a cranial landmark is strongly recommended to minimize excessive radiation exposure to the eye lens. Diagnostic image quality studies have further confirmed that the use of the SOML does not compromise diagnostic information and does not introduce image artifacts. Radiographers and radiologists are advised to re-evaluate hospital head CT protocols with careful consideration of the radiation dose received by the eyes. Regular training sessions are also encouraged to ensure that staff remain updated with current knowledge and best practices.

4 Conclusions

A comparative study evaluating diagnostic information using OML and SOML landmarks revealed no significant difference, with an independent t-test yielding a p-value of 0.7419. In contrast, eye lens dose measurements showed that selecting the SOML reduced radiation exposure by up to 85%. Accordingly, the use of the SOML landmark is strongly recommended to minimize ocular radiation dose without compromising diagnostic information or image quality.

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