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Evaluation of Radiation Dose to the Thyroid Gland on Infant Patients Undergoing Anteroposterior Chest X-Ray at a Tertiary Hospital in North-Western Nigeria

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Abstract

The study aims at measuring the entrance surface dose (ESD) of the thyroid gland of infant patients undergoing anterior-posterior (AP) chest x-ray in Usmanu Danfodiyo University Teaching Hospital Sokoto (UDUTHS). The study further determines the effective dose to the thyroid on infant patients undergoing AP chest x-ray. Also, compare the entrance surface dose of infant patients obtained from the study with other similar studies and diagnostic reference levels (DRLs) recommended by the International Commission on Radiological Protection ICRP. This is a prospective cross-sectional study and the primary source of data was obtained. Pediatric patients used for the study who are referred to the radiology department for an anteroposterior chest x-ray, UDUTH, Sokoto state, Nigeria. A non-probability sampling technique was adopted for the patient who came in for a chest x-ray (AP) and as recommended by ICRP that a minimum of 10 patients should be used to determine the ESD for each projection, therefore 15 patients were adopted for this study. The result of the ESD obtained for the thyroid on infant patients undergoing chest x-ray (AP) was averaged and the mean of the ESD was 1.38 mGy. This result was compared to similar studies done within the country and outside the country and with the European Commission on radiological protection as seen in Table 6 and Figure 3. The ESD obtained in this study is much higher than those obtained in similar studies as well as the recommended Diagnostic Reference Levels (DRLs). The method adopted in the study was recommended by the international commission on radiological protection, as a result of this, comparisons were reliably made with the reference values and similar studies. The result has shown that entrance surface doses and radiation doses to the thyroid exceed the permissible value in Usmanu Danfodiyo University Teaching Hospital (UDUTH) Sokoto.

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1. Introduction

Medical exposures are the most important source of man-made radiation to the public, and patient dose measurement is widely considered an important quality control tool in medical radiography [1]. Chest radiography is one of the most prevalent x-ray procedures in pediatrics [2, 3]. However, due to the small size of pediatric patients, it remains a concern that 95% of all pediatric chest x-rays include the neck and are associated with high radiation exposure to the thyroid gland [4]. The thyroid gland in the infant has one of the highest risk coefficients of any other organ [5, 6]. The correlation between the high level of radiation and thyroid cancer, particularly in young children has been established [6, 7]. The increased risk of thyroid cancer from low levels of medical diagnostic X-rays has also been highlighted [8, 9]. Moreover, in contrast to the adults, as pediatric patients are unable to sit up or stand on their own their chest radiographs are routinely performed in anterior-posterior (AP) view instead of posterior-anterior (PA) view and consequently, their thyroid gland is irradiated [10-12].

Absorbed dose deposited gives no information on the damaging effect of ionizing radiation [10]. However, measurement of dose (dosimetry) can be used to estimate the effective dose which gives us a clue as to the damaging effect of radiation by obtaining whole body dose equivalent [13, 14]. Relevant regulatory bodies are responsible for publishing Diagnostic Reference Levels (DRLs) such as the international commission on radiological protection (ICRP) and International Atomic Energy Agency (IAEA). Each radio-diagnostic department is charged with measuring the dose received by their patients and comparing it with the standard values. If the DRLs values for any procedure are exceeded consistently an investigation should be undertaken without undue delay to determine possible reasons and a corrective action plan should be implemented and documented (ICRP). Since the introduction of the term Diagnostic Reference Levels (DRLs) by the International Commission on Radiological Protection in 1996 (ICRP, 1996) [15], there have been continuing worldwide efforts to develop and implement DRLs in diagnostic radiology as well as nuclear medicine. Diagnostic Reference Levels help to avoid radiation dose to the patient that does not contribute to medical diagnosis [16, 17]. The international commission on radiological protection (ICRP) in its 1996 publication recommended that to set DRLs and identify unusually high exposure levels, the radiation quantity assessed should be easily measurable. European Commission 1996 stated the Diagnostic Reference level for an infant undergoing anterior-posterior chest x-ray is 0.08mGy. The DRLs are measured by placing a thermoluminescent dosimeter (TLD) on the patient's entrance skin, thereby measuring the entrance surface dose. In first-world countries with advanced medical systems, guidelines for medical exposures and clinical applications have been established many years ago [18, 19]. To the best of the researchers' knowledge, there is no evidence that any study evaluated the radiation exposure to the thyroid gland in pediatric chest x-rays in Nigeria. The main purpose of this study is to measure the entrance surface dose to the thyroid region for pediatric chest radiography and compare the mean surface dose value with the previous studies to help in optimizing chest radiography.

2. Materials and methods

This is a prospective cross-sectional study and the primary source of data was obtained. Pediatric patients used for the study who are referred to the radiology department for an anterior-posterior chest x-ray, UDUTH, Sokoto state, Nigeria. A non-probability sampling technique was adopted for the patient who came in for a chest x-ray (AP) and as recommended by ICRP that a minimum of 10 patients should be used to determine the ESD for each projection, therefore 15 patients were adopted for this study.

Ethical approval was obtained from the Usmanu Danfodiyo University Teaching Hospital Sokoto ethical committee before the commencement of the research. The inclusion criteria for this study are infant patients with an average weight of (10±5kg) referred to the radiology department UDUTHS based on the recommendation of European guidelines on DRLs for pediatric imaging (complete draft for PiDRLs Workshop, 30 September 2015) standard mean weight of 10±5kg emphasizing weight distribution of the local region of study. The exclusion criteria are Infant patients with co-morbidities that need over or under-exposure.

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Table 1. Specifications of the machine used

Manufacturer	GE Rad/Diamond Varian Medical System X-ray Product
Model Number Type	2226680/RAD-12
Year of Manufacture	2007
Year of installation	2010
Total Filtration	2.6mmAl
Intensifying Screen Type	Blue emitting (fast screen) standard and Green emitting (slow screen) standard
Film Type	Blue sensitive (Monochromatic)
Processor	Manual
Fine Focus	0.6
Broad focus	1.2
Generator Waveform	3-Phase-12 Pulse generator

Table 2. Biometric data in average and range

Examination	Weight (kg)	Height (cm)	Age
Chest x-ray (AP)	8.2(5-12)	62.9(55.5-80)	8(6-11)

The ages of the patients were obtained by direct questioning of the patient's mother or relative, the weight was obtained by objective measurement using an electronic weighing scale. One TLD each was placed on the neck of the patient. The technical factors (kVp, mAs, FFD, and FSD) were recorded from the control console during each examination. The x-ray machine used was a GE Rad/Diamond x-ray tube with an added filtration of 1.5Al, 0.6 - 1.2 focal spot size, and a maximum tube voltage of 150kVp. The highly sensitive TLD chips used were produced by Racard (GR-100, Li, 6Li, 7Li) with a dimension of the disc 0.45mmx0.9mm, chip 3.2mm x 3.2mm x 0.9mm, microcube 1mmx1mmx1mm, rod 1mmx1mm and has a thin layer pallet of 45mmx0.9mm (0.05mm thin layer). The obtained data were processed with a RadPro Cube 400 TLD reader (Freiberg Instrument, GmbH, Germany), having a measurement chamber containing a PMT Tube module, Heating Unit, Exchangeable Filter unit, and nitrogen gas supply unit. Other materials were circular Crystals (chips) with a dimension of 3.2 mm x 3.2 mm x 0.9 mm, and a TLD heater which was used to anneal the chips. A pre-calibrated RadPro Cube 400 TLD reader was used to determine the corresponding count from each exposed chip which was initially calibrated by the Secondary Standard Dosimetry Laboratory (SSDL) in Nigeria which is the National Institute of Radiation Protection and Research (NIRPR) at the University of Ibadan, Oyo State and was all annealed at 400oc for one hour for the first stage and annealed at 100oc for another two hours to remove lower peaks using a TLD heater. Similarly, background/transport count from controlled chips was noted and deducted from the exposed chips. The counts obtained were later multiplied by the calibration factor of the chips to obtain the corresponding estimated dose (mSv). The accumulated dose for a period of five (5) days, which was equivalent to one week was calculated from the following equation:

Dose (mSv)=Count $\times$Calibration Factor

Where the Calibration factor is a constant obtained from the dose response from an SSDL. The mean of the values obtained will be calculated and the standard deviation of the effective values was determined using Microsoft Excel.

3. Results/Discussion

The specifications of the x-ray machine, image acquisition device, and processor used in this study are represented in Table 1.

A summarization of the patient characteristics which are consistent with the requirement for determining the ESD and effective dose to the thyroid gland of infants in terms of age and weight is represented in Table 2. The mean weight was within the acceptable range (10±5kg) and the range of patients' ages falls within the infant age range.

The mean value of the technical exposure factors used in the study is represented in Table 3. Arrested inspiration and stability of the patients were carefully monitored during exposure.

The descriptive and inferential statistical analysis of ESD in the thyroid gland of pediatric patients is represented in Table 4.

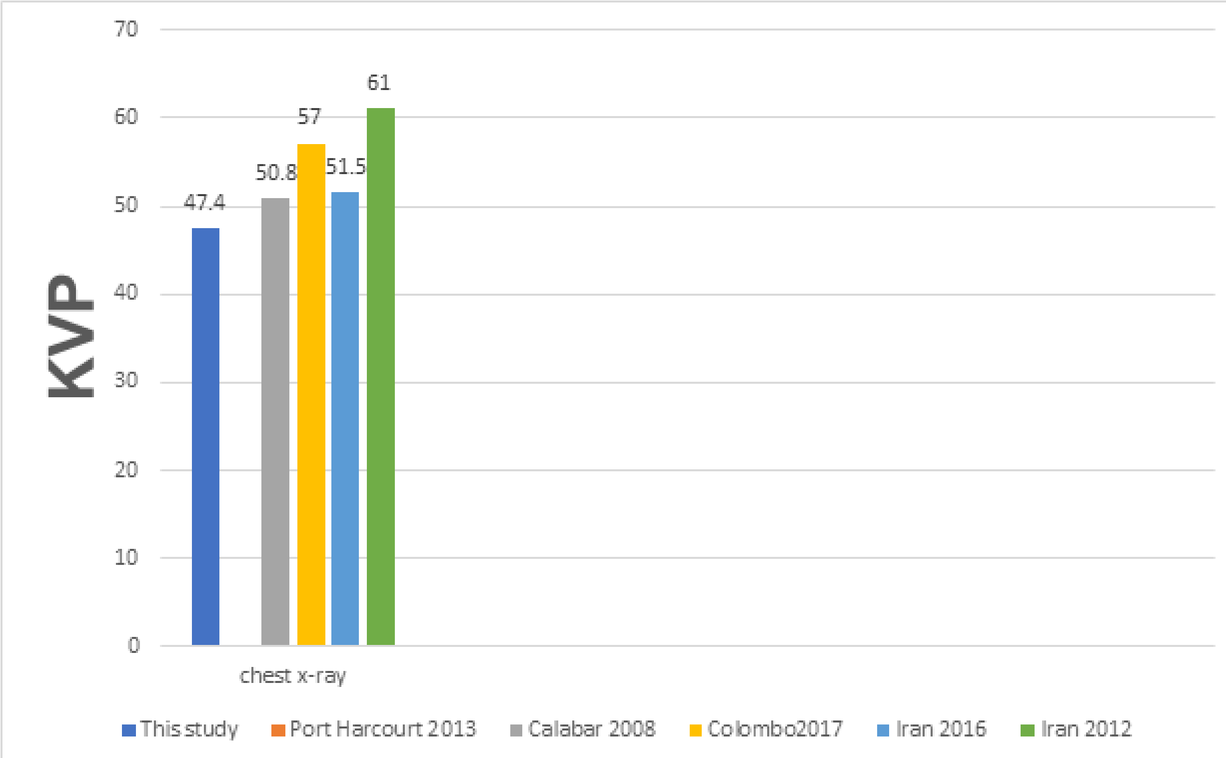

Figure 1. Comparison of mean radiographic exposure parameter (kVp) with other studies
kVp: kilo-voltage peak

Table 3. Mean values and range of technical parameters for the examination

Examination	Tube Potential (kVp)	Current-time (mAs)	Focus-film Distance (cm)	Film-skin Distance (cm)
Chest x-ray (AP)	46.5 (43-50)	9 (8-10)	115 (110-120)	92.5 (85-100)

Table 4. Statistical description (mean, median, min and max) of the ESD (mGy) values

Examination	Number of patient	Mean (mGy)	Median (mGy)	Standard deviation	Minimum (mGy)	Maximum (mGy)	Effective dose (mSv)
Chest x-ray AP	15	1.38	1.81	0.77	0.08	2.74	0.057

Table 5. Comparison of mean radiographic exposure parameters with other studies

Study	Examination	kVp	mAs
This study	Chest x-ray AP	47.4	10
Calabar Egbe *et al,* 2008 [20].	Chest x-ray AP/PA	50.8	3.3
Colombo Herat*h et al,* 2017 [21].	Chest x-ray AP	57	4.62
Iran Karami *et al*, 2016 [10].	Chest x-ray AP	51.5	4.06
IranToosi and Asadinezhad 2012 [22].	Chest x-ray AP	61	5

The different technical parameters used in similar studies (local and international) are represented in Table 5. However, their studies exclude focusing on skin distance.

The comparison of measured mean entrance surface dose with other related studies is represented in Table 6. It

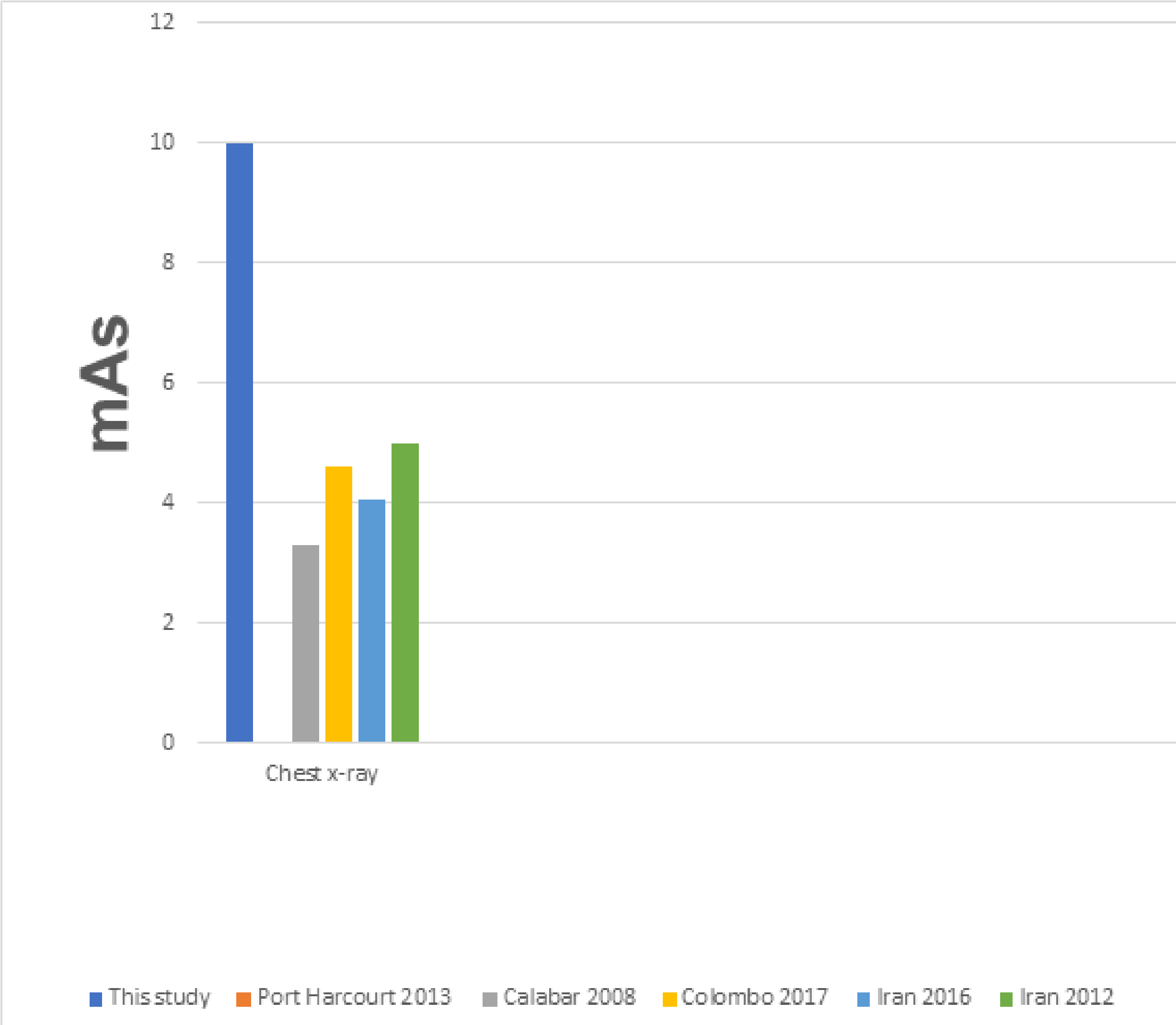

Figure 2. Comparison of mean radiographic exposure parameter (mAs) with other studies

mAs: milli-ampere second

Table 6. Comparison of measured mean ESD (mGy) values within other studies

Study	**Examination**	**Age**	**ESD (mGy)**
This study	Chest x-ray AP	>1	1.38
Calabar Egbe *et al,* 2008 [20].	Chest x-ray AP/PA	>1	0.064
Colombo Herath *et al,* 2017 [21].	Chest x-ray AP	>1	0.0208
Iran Karami *et al*, 2016 [10].	Chest x-ray AP	>1	0.065
IranToosi and Asadinezhad 2012 [22].	Chest x-ray AP	>1	0.076

revealed that the ESD values within this study are much higher than both the recommended value and values observed in similar studies.

The result of the ESD obtained for the thyroid on infant patients undergoing chest x-ray (AP) was averaged and the mean of the ESD was 1.38 mGy. This result was compared to similar studies done within the country and outside

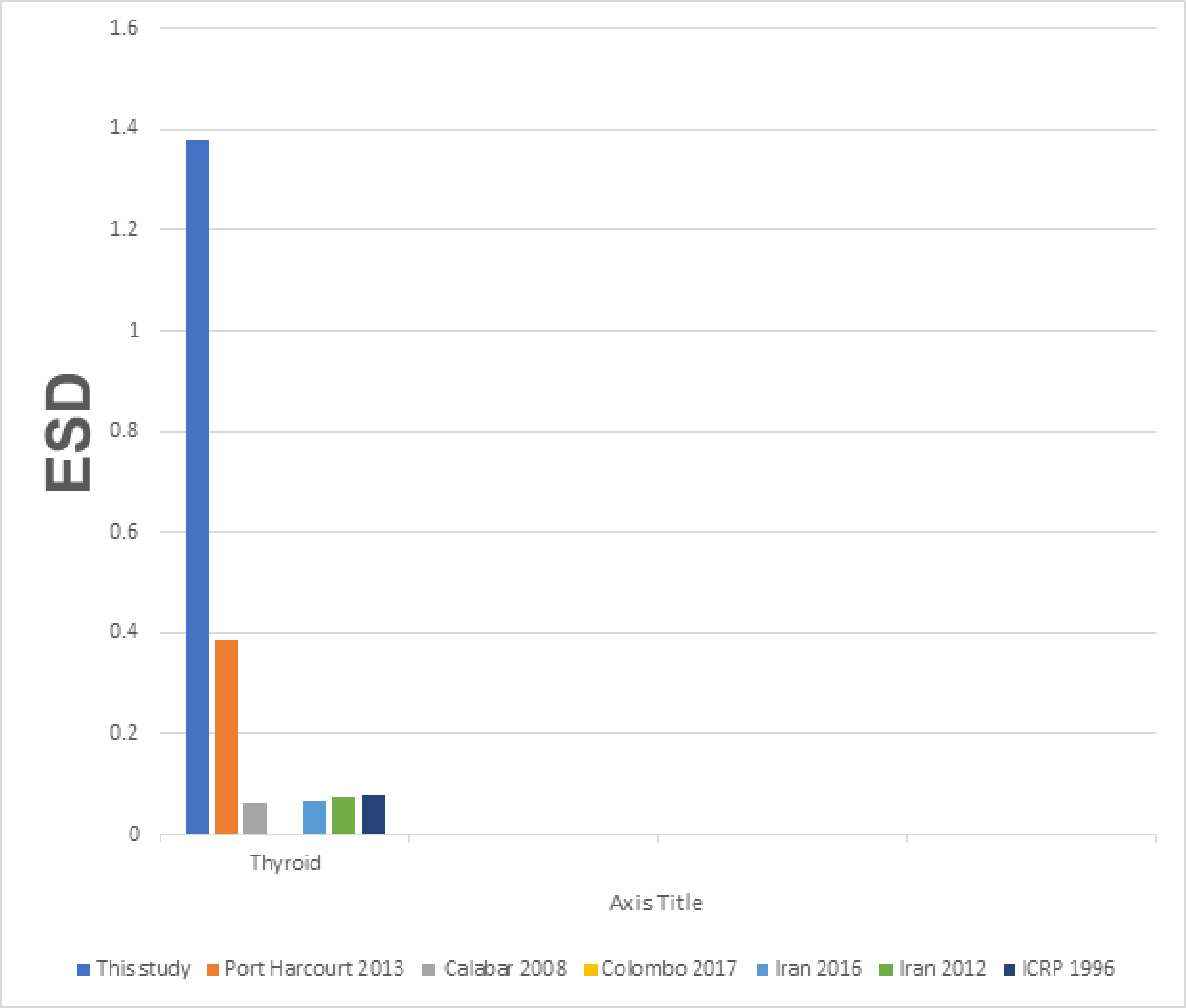

Figure 3. Comparison of measured mean ESD (mGy) values with other studies
ESD: Entrance surface dose

the country and with the European Commission on radiological protection as seen in Table 6 and Figure 3. The ESD obtained in this study is much higher than those obtained in similar studies as well as the recommended DRL.

The international commission on radiological protection (2017) proposed the standardization of infant size through the size restriction recommended the range of 5-10kg or a range depending on the weight distribution of the patient sizes in the region of the study to achieve a mean weight of 10kg. the mean weight of the patients in this study falls within the acceptable range of 15±10kg.

Although there are several methods of quantifying the absorbed dose at the surface of the body, the most preferred method is used of thermoluminescent dosimeter [23.24]. The reasons for these preferences are: the TLD has a high tissue equivalence, measurements obtained can be taken as the true values of the absorbed dose; it is easy to place on the patient's actual surface; it measures backscatter radiation. It has a very long half-life [25-28].

The ESD value obtained in this study is much higher than the DRL of other related studies (Tables 3 and 5). The main reason was related to using a high tube current (mAs) and a low tube potential (kVp) as well as failure to use a thyroid shield during the examination (chest x-ray AP). A similar comparison of kVp and mAs with related studies are seen in Figure 2 and 3. The makeup of the equipment is the film/screen combination and the strength of the processing chemicals are all factors that contribute to the quality of the final image. The use of a manual processor unit involving the developer and fixer is also another contributing factor to the final density of the image. The center where this study was carried out uses a manual processor for latent image processing. As consequence, the film density can be manually controlled until the density of the operator's choice has been reached.

4. Conclusion

The method adopted in the study was recommended by the international commission on radiological protection, as a result of this, comparisons were reliably made with the reference values and similar studies. The result has shown that entrance surface doses and radiation doses to the thyroid exceed the permissible value in Usmanu Danfodiyo University Teaching Hospital (UDUTH) Sokoto. This research can be extended by using digital radiography and computed radiography system to measure ESD to the thyroid during AP chest projection of pediatrics.

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