REVIEW ARTICLE

Comparing subjective and objective image quality at two different radiation exposure ranges of the paranasal sinus CT examinations using a volumetric 320-row detector CT system

¹Berhan Pirimoglu, ¹Recep Sade, ²Muhammed Sedat Sakat, ¹Hayri Ogul, ¹Suat Eren and ¹Mecit Kantarci

¹Department of Radiology, Ataturk University, Medical Faculty, Erzurum, Turkey; ²Department of Otorhinolaryngology, Ataturk University, Medical Faculty, Erzurum, Turkey

Objectives: To evaluate image quality of protocol including 135 kVp, 5 mAs and 80 kVp, 5 mAs in the paranasal sinus CT examinations using single volumetric 320-row multidetector CT technique.

Methods: From September to December 2016, both of our control group including 135 kVp and 5 mAs and our study group including 80 kVp and 5 mAs paranasal CT protocols were simultaneously performed on 40 patients using single volumetric 320-row multidetector CT device. Image quality for bony structures, air-filled structures and soft tissues were independently assessed for each group by three blinded observers using a 3-point grading scale (0 = not diagnostic, 1 = partially diagnostic, 2 = diagnostic). Objective image quality was also performed by region of interests were placed on axial soft tissue reconstructions in both eye bulbs, retrobulbar fat and maxillary sinuses to obtain different values for aqueous tissue, soft tissue and air, respectively. Effective dose was calculated from the dose-length product.

Results: The effective radiation dose which calculated for the control group scans was 0.037 ± 0.003 mSv. But, it was 0.0099 ± 0.001 mSv for the study group scans. The effective radiation dose of study group was statistically significant lower than control group ($p < 0.001$). Despite significant lowering of the radiation doses, image qualities were sufficient for evaluating all the bony structures, air-filled structures and soft tissues except for eye muscle, retrobulbar fat and eye bulb.

Conclusions: Our results present that our protocols for study and control group provide significant dose reduction without the loss of diagnostic image quality for paranasal sinus CT. Paranasal sinus CT imaging can be performed at very low radiation exposure maintaining high image quality using a single volume 320-row detector CT device using 135 kVp and 5 mAs.

Dentomaxillofacial Radiology (2017) **46**, 20170212. doi: [dmfr.20170212](https://doi.org/10.1111/dmfr.20170212)

Cite this article as: Pirimoglu B, Sade R, Sakat MS, Ogul H, Eren S, Kantarci M. Comparing subjective and objective image quality at two different radiation exposure ranges of the paranasal sinus CT examinations using a volumetric 320-row detector CT system. *Dentomaxillofac Radiol* 2017; **46**: 20170212.

Keywords: low radiation dose; paranasal sinus; volumetric; 320-row detector CT

Introduction

CT is the primary imaging technique used to assess inflammatory diseases. It is the gold standard radiologic examination of the paranasal sinuses. It usually

diagnoses acute and chronic sinusitis to differentiate mucosal disease patterns. It is also beneficial before functional endoscopic sinus surgery to evaluate individual anatomic variants and the extent of disease.¹⁻⁴ Multidetector CT technology is a useful diagnostic tool with high spatial resolution. Radiation exposure during

Correspondence to: Dr Berhan Pirimoglu, E-mail: berhan.dr@gmail.com

Received 17 February 2017; revised 7 August 2017; accepted 30 August 2017

paranasal sinus CT examination is a major concern because the radiation-sensitive optic lens and thyroid gland are included in the scanning field.⁵⁻⁷

Recently, CT imaging procedures have seen emerging technologies such as larger detectors, faster rotation tubes, new multidetectors and image reconstruction algorithms as well as combinations of those.⁸⁻¹⁰ The most recent developments like the 320-row detector facilitate volume CT and helps to avoid the over-beaming effect of helical scanning. This significantly contributes to dose minimization for CT imaging examinations while speeding up the investigation and thus decreasing the duration time. The 320-row multidetector volume CT offers several advantages to reduce CT dose while maintaining image quality. There are many advantages of the single volume CT acquisition including no helical overlap, decreased radiation dose and no helical scan. As a result, radiation dose can decrease by as much as 80%.^{11,12}

In recent years, various articles about dose reduction strategies in paranasal sinus CT imaging have been published.^{2,4,5,7,13} However; to the best of our knowledge, our study is the first original research evaluation of the paranasal sinus CT imaging protocols using volumetric 320-row detector CT system. In this study, we aim to compare two paranasal CT protocols: one with 135 kVp tube voltage and 5 mAs current and one with 80 kVp tube voltage and 5 mAs current. We also aim to

evaluate subjective and objective image quality of these two paranasal sinus CT protocols using a volumetric 320-row multidetector CT technique.

Methods and materials

Phantom study

Examinations were performed on a phantom head. For this study, a 320-row multidetector CT device (Aquilion ONE Vision; Toshiba Medical Systems Corporation, Otawara, Japan) was used to examine the phantom head. All CT scans were performed with a wide volume acquisition technique with parameters recommended by the manufacturer (slice thickness, 0.5 mm; rotation time, 0.5 s and a scan range of 160 mm (320 slices × 0.5 mm, Supplementary file 1, supplementary material available online). 19 examinations (Supplementary file 2) were conducted with different settings of the tube voltage and current (Table 1). Dose measurements were derived from the study protocol as volume CT dose index (CTDI_{vol}) and dose-length product (DLP).

Table 1 summarizes the examination parameters for the phantom imaging studies. Image qualities of all the phantom images were assessed using a 10-point scale (1: non-diagnostic to 10: excellent image quality) by observer 1, 2 and 3. The protocol of the control group included the tube voltage of 135 kV and a tube current of 5 mAs based on the results of the present phantom study (Table 1). The

Table 1 Examination parameters, the corresponding radiation doses and image quality scores for radiologist 1, 2 and 3 in phantom study

Tube voltage (kVp)	Tube current (mA-mAs)	CTDI _{vol} (mGy) ^a	DLP ^a (mGy × cm)	Image quality scores		
				Radiologist 1	Radiologist 2	Radiologist 3
120	150-75	13.7	191.2	10	10	10
135	100-50	12	168.5	10	10	10
120	100-50	9.1	127.5	10	10	10
100	150-75	8.8	122.6	10	10	10
135	50-25	6	84.3	10	10	10
100	100-50	5.8	81.8	10	10	10
80	150-75	4.7	65.7	10	10	10
120	50-25	4.6	63.7	10	10	10
80	100-50	3.1	43.8	10	10	10
135	25-12.5	3	42.1	10	10	10
100	50-25	2.9	40.9	10	10	10
120	25-12.5	2.3	31.9	10	10	10
80	50-25	1.6	21.9	10	10	10
100	25-12.5	1.5	20.4	10	10	10
135 ^a	10-5 ^a	1.2	16.9	10	10	10
120	10-5	0.9	12.7	10	9	9
80	25-12.5	0.8	10.9	9	8	8
100	10-5	0.6	8.2	7	6	7
80	10-5	0.3	4.4	6	6	6

CTDI_{vol}, volume CT dose index; DLP, dose-length product; kVp, kilovolts peak; mA, miliampere; mAs, miliampere second.

^aThe corresponding radiation doses are listed from the highest to the lowest. Bold italic line refers to the protocol including tube voltage 135 kV and tube current 5 mAs was chosen based on the results of present phantom study.

lowest dose that our 320-row multidetector CT device can perform was chosen based on the results of the present phantom study. The study group included a tube voltage 80 kV and tube current 5 mAs.

Patients

Between September and December 2016, 64 consecutive patients scheduled for paranasal sinus CT for suspected inflammatory mucosal disease were included into our study. 19 of the 64 patients did not agree with our paranasal CT imaging protocols and were excluded. 5 of 64 consecutive patients with contrast media administration (suspicious for abscess or neoplasm) were excluded. A total of 40 patients met the inclusion criteria. Both the paranasal sinus CT protocols including 135 kVp and 5 mAs and including 80 kVp and 5 mAs were simultaneously performed on these 40 patients. CT images obtained from the protocol with 135 kVp and 5 mAs were assigned to the control group; CT images obtained from the protocol with 80 kVp and 5 mAs were also assigned to the study group. All patients signed informed consent and the study protocol was approved by the local institutional review board.

CT acquisition protocols

All paranasal CT examinations were performed on a 320-row detector CT (Aquilion ONE Vision; Toshiba Medical Systems Corporation, Otawara, Japan) in single volume mode with an acquisition in single volume covering the paranasal region including from the roof of the frontal sinuses to the alveolar process of the maxillary sinus for both study and control groups. The paranasal CT protocols for control and study groups were performed concurrently.

In the control group, the CT acquisition protocol was performed with the following parameters: 0.5 s gantry rotation time, 192×0.6 mm collimation using a z-flying focal spot, 5 mAs tube current and 135 kVp tube voltage. In the study group, the CT acquisition protocol was performed with the following parameters: 0.5 s gantry rotation time, 192×0.6 mm collimation using a z-flying focal spot, 5 mAs tube current and 80 kVp tube voltage. The patients were supine with a slight reclination of the head to obtain a parallel alignment of the upper jaw to the gantry. These minimized artefacts from the dental hardware in both groups. The 3-mm axial, 3-mm coronal and 3-mm sagittal images were reconstructed from the raw data.

Evaluation of subjective image quality

All imaging parameters were evaluated independently by two radiologists with 5 and 3 years of experience in maxillofacial imaging; and one otorhinolaryngologist with 1 year of experience in maxillofacial imaging were blinded to all clinical data on a 3D workstation (SyngoVia VB 10B, Siemens Healthcare, Erlangen, Germany). The conspicuity of important anatomic landmarks was assigned a score of 0, 1 or 2 (not diagnostic, partially diagnostic

or diagnostic, respectively). The following anatomic landmarks were assessed for each side: bone structures (including; ethmoidal bony septa, lamina papyracea, maxillary bone, sphenoid bone and nasal bony septa), air-filled structures (including; maxillary sinuses, sphenoidal sinuses, frontal sinuses, ethmoidal cells and ostium of maxillary sinus) and soft tissues (including; concha, eye bulb, eye muscle, retrobulbar fat, nasolacrimal duct and skin) were evaluated independently by these same three observers. These anatomic landmarks were chosen based on the two previous studies.^{5,13}

Evaluation of the objective image quality

To compare the objective parameters between the control and study group images, noise was measured by three 10 mm² region of interest placed with consensus on the axial soft tissue reconstructions in both eye bulbs, retrobulbar fat and maxillary sinuses to obtain different values for aqueous tissue, soft tissue and air, respectively. Noise was defined as the mean standard deviation of attenuations measured in Hounsfield units. Fully obstructed sinuses were excluded to avoid confounding of the noise measurement in the maxillary sinuses.

Estimation of effective radiation exposure

The effective radiation dose of the study and control groups were calculated via a method proposed by the measurement, reporting and management of radiation dose in CT. These use the DLP and a conversion coefficient for the adult head ($k = 0.0021$ mSv/[mGy cm]); the DLP values were derived from the patient protocol.¹⁴ All dose data for the study and control CT examinations were evaluated by using Radimetrics (Bayer, Boulevard, Whippany, NJ) commercial dose-reporting software.¹⁵

Statistical analysis

Statistical analyses were performed using SPSS 22.0 (SPSS Inc., Chicago, IL). One-way analysis of variance and χ^2 tests were used to compare the continuous and categorical variables between the study and control groups. Mann–Whitney U test was performed in comparing the objective image quality. We calculated interobserver agreements for all observers. An interobserver reliability analysis using the kappa statistic was performed to determine the consistency among observers. The degree of agreement is based on kappa values and was as follows: <0, none; 0–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1.00, almost perfect. The p values < 0.05 were considered to be statistically significant.

Results

The same 40 patients were used in the study and control group (31 (77.5%) males, 9 (22.5%) females). The mean age of the patient was 34.6 ± 15.25 years. The effective radiation dose was calculated for the control group

Figure 1 Coronal volume CT with 135 kVp and 5 mAs (a) and volume CT with 80 kVp and 5 mAs (b) images of a 19-year-old male shows mucosal thickening in the right maxillary sinuses. Volume CT with 80 kVp and 5 mAs (b) images were blurred so mucosal thickening could not be evaluated.

scans and was 0.037 ± 0.003 mSv. The effective radiation dose was calculated for the study group scans and was 0.0099 ± 0.001 mSv. The effective radiation dose of the study group was statistically significant lower than the control group ($p < 0.001$).

We obtained an overall interobserver agreement between observer 1 and 2 of 0.98, between observer 1 and 3 was 0.79 and between observer 2 and 3 also was 0.81. This was used to evaluate all bony structures, air-filled structures, and soft tissues (Figure 1). In observer 1, the lowest mean diagnostic values were 0.38 and 0.05 for evaluating the eye muscle and retrobulbar fat in the study group, respectively ($p = 0.001$). For observer 2, the lowest mean diagnostic values were 1.53 and 1.63. This was used to evaluate the eye muscle and eye bulb in the study group, respectively ($p = 0.001$). For the observer 3, the lowest mean diagnostic values were 1.75 and 1.83 in evaluating of eye muscle and retrobulbar fat in the study group ($p = 0.001$ and $p = 0.006$, respectively) (Figure 2). The overall mean diagnostic values were 1.71, 1.73 and 1.92 in the study group for observers 1, 2 and 3, respectively. The overall mean diagnostic values were 1.87, 1.95 and 1.99 in the control group, respectively. Despite the significant lowering of the radiation doses, image qualities were sufficient for evaluating all bony structures, air-filled structures (Figure 3) and soft tissues except for the eye muscle, retrobulbar fat and eye bulb (Figure 4). All mean diagnostic and kappa values for all observers are summarized in Table 2.

Figure 2 Coronal volume CT with 135 kVp and 5 mAs (a) and volume CT with 80 kVp and 5 mAs (b) images of a 21-year-old male shows normal orbital muscles and fat. Volume CT with 80 kVp and 5 mAs (b) images were blurred so orbital muscles and fat could not be evaluated.

Figure 3 Axial volume CT with 135 kVp and 5 mAs (a) and volume CT with 80 kVp and 5 mAs (b) images of a 32-year-old female shows normal ethmoidal air cells. Volume CT with 80 kVp and 5 mAs (b) images were blurred so it seemed to be mucosal thickening in ethmoidal air cell.

The mean attenuation values of control group obtained from the eye bulb, retrobulbar fat and air were higher than the study group ($p = 0.039$, $p = 0.045$ and $p = 0.048$, respectively). Table 3 shows the mean attenuation and standard deviation of the evaluated structures for noise measurements in the control and study groups.

Discussion

This study describes image quality for the latest generation of 320-row multidetector volumetric CT technology for paranasal sinus examinations. Our results for the paranasal sinus CT protocol in the control group are feasible with optimal diagnostic image quality and very low radiation exposure at 135 kVp and 5 mAs. We also found satisfactory imaging quality for bone structures, soft tissues and air-filled structures except for eye muscle, retrobulbar fat and eye bulb at 80 kVp and 5 mAs.

We know that plain Waters view radiographic images are inadequate for assessing the complex anatomy of the paranasal sinuses. In one study, Chaparian et al¹⁶ evaluated organ doses, effective doses and the corresponding risk of exposure-induced cancer death

Figure 4 Axial volume CT with 135 kVp and 5 mAs (a) and volume CT with 80 kVp and 5 mAs (b) images of a 23-year-old male shows normal orbital muscles, optic nerve and retro bulbar fat. Volume CT with 80 kVp and 5 mAs (b) images were blurred so orbital muscles, optic nerve and retro bulbar fat could not be evaluated.

Table 2 The mean diagnostic values of study and control group for each observer

	Observer 1 (otorhinolaryngologist)			Observer 2 (radiologist)			Observer 3 (radiologist)			Kappa value for observer 1 and 2			Kappa value for observer 1 and 3			Kappa value for observer 2 and 3		
	Study group	Control group	p-value	Study group	Control group	p-value	Study group	Control group	p-value	Study group	Control group	p-value	Study group	Control group	p-value	Study group	Control group	p-value
Ethmoidal bony septa	1.98	2	0.317	1.83	2	0.006	2	2	1	0.85	0.98	0.83	0.85	0.98	0.83	0.85	0.98	0.83
Lamina papyracea	1.93	2	0.079	1.63	1.93	0.001	1.98	2	0.32	0.70	0.95	0.65	0.70	0.95	0.65	0.70	0.95	0.65
Maxillary bone	1.98	2	0.317	1.75	2	0.001	1.92	2	0.08	0.77	0.94	0.83	0.77	0.94	0.83	0.77	0.94	0.83
sphenoid bone	2	2	1	1.9	2	0.041	2	2	1	0.90	1.00	0.90	0.90	1.00	0.90	0.90	1.00	0.90
Nasal bony septa	1.98	2	0.317	1.65	2	0.001	2	2	1	0.67	0.98	0.65	0.67	0.98	0.65	0.67	0.98	0.65
Bones overall	1.97	2	0.151	1.75	1.98	0.001	1.98	2	0.41	0.78	0.99	0.77	0.78	0.99	0.77	0.78	0.99	0.77
Maxillary sinuses	2	2	1	1.83	2	0.006	1.83	2	0.006	0.83	0.8	1.00	0.83	0.8	1.00	0.83	0.8	1.00
Sphenoidal sinuses	1.98	2	0.317	1.9	2	0.041	1.98	2	0.32	0.92	1.00	0.92	0.92	1.00	0.92	0.92	1.00	0.92
Frontal sinuses	2	2	1	1.88	2	0.022	2	2	1	0.88	1.00	0.88	0.88	1.00	0.88	0.88	1.00	0.88
Ethmoidal cells	1.94	1.94	1	1.6	1.8	0.052	1.78	1.96	0.13	0.66	0.85	0.82	0.66	0.85	0.82	0.66	0.85	0.82
Ostium of maxillary sinus	1.65	2	0.001	1.6	1.78	0.183	1.82	1.92	1	0.95	0.83	0.78	0.95	0.83	0.78	0.95	0.83	0.78
Air filled structures overall	1.92	1.98	0.001	1.76	1.92	0.001	1.88	1.98	0.031	0.84	0.94	0.88	0.84	0.94	0.88	0.84	0.94	0.88
Concha	2	2	1	1.88	2	0.022	2	2	1	0.88	1.00	0.88	0.88	1.00	0.88	0.88	1.00	0.88
Eye bulb	1.78	2	0.002	1.63	2	0.001	2	2	1	0.85	0.78	0.63	0.85	0.78	0.63	0.85	0.78	0.63
Eye muscle	0.38	1.38	0.001	1.53	2	0.001	1.75	2	0.001	0.2	0.35	0.78	0.2	0.35	0.78	0.2	0.35	0.78
Retrolubal fat	0.05	0.71	0.001	1.68	2	0.001	1.83	2	0.006	0.1	0.1	0.85	0.1	0.1	0.85	0.1	0.1	0.85
Nasolacrimal duct	1.75	1.84	0.155	1.65	1.80	0.190	1.85	1.96	0.5	0.90	0.90	0.80	0.90	0.90	0.80	0.90	0.90	0.80
Skin	2	2	1	1.78	2	0.002	2	2	1	0.78	1.00	0.78	0.78	1.00	0.78	0.78	1.00	0.78
Soft tissue overall	1.32	1.62	0.001	1.69	1.97	0.001	1.9	1.99	0.01	0.63	0.42	0.79	0.63	0.42	0.79	0.63	0.42	0.79
Overall	1.71	1.87	0.001	1.73	1.95	0.001	1.92	1.99	0.001	0.98	0.79	0.81	0.98	0.79	0.81	0.98	0.79	0.81

Table 3 The mean attenuation and standard deviation values of the evaluated structures in study and control group

	Control group		Study group	
	Mean attenuation(HU)	Standard deviation	Mean attenuation (HU)	Standard deviation
Eye bulb	26	12	5	11
Retrobulbar fat	−128	13	−82	14
Air (from maxillary sinuses)	−995	6	−950	8

HU, Hounsfield unit.

Image noise is defined as mean SD of measured Hounsfield units and is given as mean and SD.

resulting from paranasal sinus radiography for male and female patients in all age groups. They found that the mean effective dose was 0.039 mSv from the plain paranasal sinus radiography in adults. Their mean radiation dose was close to our paranasal CT protocol of the control group, but the paranasal CT protocol of the study group was much lower than their results from conventional radiography imaging.

Our results show that significantly lowering the radiation dose using a volumetric 320-row detector CT technique did not decrease the image quality in the paranasal sinus imaging examinations. Important bony structures and anatomical landmarks were very well defined with our paranasal CT protocols for the study and control group. However; soft tissue structures such as the eye muscle, retrobulbar fat and eye bulb were relatively well defined only in the study group protocol. One reason for the loss of image quality in evaluating the soft tissues using our study group protocol could be increased noise and photon starvation in soft tissues such as eye muscle and the eye bulb.

One recent trending topic in paranasal sinus CT imaging examinations is minimizing the radiation exposure to the lowest degree possible without decreasing the diagnostic quality. Therefore, the radiation exposure associated with CT is a major concern especially, for radiation-sensitive tissues such as the eye lenses and thyroid gland for repeated examinations.^{7,13,17}

Tack *et al*² studied two doses for head imaging: 120 kV and 10 effective mAs multidetector CT of the paranasal sinuses as well as a standard dose with 120 kV and 50 mAs with multidetector CT. The cohort was 50 patients suspected of chronic sinusitis. The CT protocol for the study dose delivered a mean radiation dose of 0.047 mSv in males and 0.051 mSv in females. The standard dose multidetector CT protocol delivered a mean radiation dose of 0.70 mSv in males and 0.76 mSv in females. They used four-channel multidetector CT scanner. However, we show the mean radiation dose was 0.037 ± 0.003 mSv in our control group protocol and was 0.0099 ± 0.001 mSv in study group protocol with a single volume 320-row detector CT device. Their mean radiation dose results were higher than our findings.

The development of 320-row CT enables axial volumetric scanning up to 16 cm in the z-axis with a single rotation. Although helical imaging reveals excessive

radiation exposure because of over-ranging, the volume mode of 320-row CT avoids the over-ranging of helical scanning.^{18,19} To the best of our knowledge, there are no previous studies of image quality in single volume 320-row detector CT in paranasal sinus imaging. Our study revealed that a volume 320-row detector CT could offer significantly lower radiation dose while preserving image quality.

Previously, Aksoy *et al*²⁰ also used a second-generation dual-source CT with high-pitch technology for detecting important paranasal sinus anatomic landmarks and pathologies. They divided the patients into three groups using tube voltages and currents for the groups; these were 80 kV/18 mA (Group 1), 80 kV/126 mA (Group 2), and 120 kV/80 mA (Group 3), respectively. They found that the mean effective doses were 0.019 ± 0.0018 mSv in Group 1, 0.08 ± 0.01 mSv in Group 2, and 0.35 ± 0.026 mSv in Group 3. One of their mean effective doses (Group 1) was lower than ours, but the remaining two mean effective doses were significantly higher than ours. In addition, their anatomic landmark scores were lower in Group 1. We obtained good imaging quality using 135 kV and 5 mAs with a single volume 320-row detector CT device. For the definition of important anatomical landmarks, particularly for determination of bony structures, soft tissues and air-filled structures are important to otorhinolaryngologists before surgical operations. Hence, our paranasal CT imaging protocol for the control group might be preferred.

Lell *et al*²¹ studied cadaver heads on a third-generation dual-source CT system with five different settings of the tube current (25, 50, 100, 150, 200 mAs) and seven different tube-voltage settings (70, 80, 90, 100, “Sn 100”, 120 and “Sn 150” kV). Sn means an additional pre-filtration of the X-ray beam with a tin filter to constrict the energy spectrum. They identified that the most dose-effective combination for trauma imaging was Sn 100 kV/250 mAs (CTDI_{vol} , 2.02 mSv) and for preoperative sinus surgery planning, Sn 100 kV/150 mAs (CTDI_{vol} , 1.22 mSv). They saw low radiation exposure via Sn 100 and Sn 150 kV protocols using a tin filter. However, their low radiation dose results were higher than our findings. Our CT protocol for the study group also has sufficient diagnostic validity in evaluating the bones and air-filled structures. This results in only minimal radiation dose exposure to the patients. Thus, our paranasal CT protocol with 80 kVp and 5 mAs was preferred for evaluating bony

structures particularly in emergency departments. Paranasal sinus CT examinations with the lowest acceptable dose should be the primary aim in each paranasal sinus examinations. Concordantly, we think that our paranasal CT imaging protocols should be a gold standard imaging tool for paranasal sinus examinations.

Our study has some limitations. First, the patient cohort was relatively small. Second, we did not consider patient size or weight differences; however, those factors probably play a minor role because the paranasal sinus anatomy is usually quite similar in an adult cohort. Third, a reduction down to 5 mAs for 80 kVp protocol can lead to a higher image noise in evaluation of the eye muscle, retrobulbar fat and eye bulb. This is a technical limitation, which may hopefully be resolved by using the 320-row multidetector CT devices.

References

- Duvoisin B, Landry M, Chapuis L, Kraysenbuhl M, Schnyder P. Low-dose CT and inflammatory disease of the paranasal sinuses. *Neuroradiology* 1991; 33: 4036–. doi: <https://doi.org/10.1007/BF00598612>
- Tack D, Widelec J, De Maertelaer V, Bailly JM, Delcour C, Gevenois PA. Comparison between low-dose and standard-dose multidetector CT in patients with suspected chronic sinusitis. *AJR Am J Roentgenol* 2003; 181: 939–44. doi: <https://doi.org/10.2214/ajr.181.4.1810939>
- Dammann F. Imaging of paranasal sinuses today. *Radiologe* 2007; 47: 578–83.
- Bulla S, Blanke P, Hassepass F, Krauss T, Winterer JT, Breunig C, et al. Reducing the radiation dose for low-dose CT of the paranasal sinuses using iterative reconstruction: feasibility and image quality. *Eur J Radiol* 2012; 81: 2246–50. doi: <https://doi.org/10.1016/j.ejrad.2011.05.002>
- Wuest W, May M, Saake M, Brand M, Uder M, Lell M. Low-Dose CT of the Paranasal Sinuses: Minimizing X-Ray Exposure with Spectral Shaping. *Eur Radiol* 2016; 26: 4155–61. doi: <https://doi.org/10.1007/s00330-016-4263-0>
- Hsiao EM, Rybicki FJ, Steigner M. CT coronary angiography: 256-slice and 320-detector row scanners. *Curr Cardiol Rep* 2010; 12: 68–75. doi: <https://doi.org/10.1007/s11886-009-0075-z>
- Brem MH, Zamani AA, Riva R, Zou KH, Rumboldt Z, Hennig FF, et al. Multidetector CT of the paranasal sinus: potential for radiation dose reduction. *Radiology* 2007; 243: 847–52. doi: <https://doi.org/10.1148/radiol.2433050207>
- Schulz B, Potente S, Zangos S, Friedrichs I, Bauer RW, Kerl M, et al. Ultra-low dose dual-source high-pitch computed tomography of the paranasal sinus: diagnostic sensitivity and radiation dose. *Acta Radiol* 2012; 153: 435–40. doi: <https://doi.org/10.1258/ar.2012.110579>
- Pirimoglu B, Sade R, Ogul H, Kantarci M, Eren S, Levent A. How Can New Imaging Modalities Help in the Practice of Radiology? *Eurasian J Med* 2016; 48: 213–21. doi: <https://doi.org/10.5152/eajm.2016.0260>
- Mulkens TH, Bellinck P, Baeyaert M, Ghysen D, Van Dijck X, Mussen E, et al. Use of an automatic exposure control mechanism for dose optimization in multi-detector row CT examinations: clinical evaluation. *Radiology* 2005; 237: 213–23. doi: <https://doi.org/10.1148/radiol.2363041220>
- Kalender WA, Buchenau S, Deak P, Kellermeier M, Langner O, van Straten M, et al. Technical approaches to the optimisation of CT. *Phys Med* 2008; 24: 71–9. doi: <https://doi.org/10.1016/j.ejmp.2008.01.012>
- Gervaise A, Osemont B, Lecocq S, Noel A, Micard E, Felbinger J, et al. CT image quality improvement using Adaptive Iterative Dose Reduction with wide-volume acquisition on 320-detector CT. *Eur Radiol* 2012; 22: 295–301. doi: <https://doi.org/10.1007/s00330-011-2271-7>
- Schaafs LA, Lenk J, Hamm B, Niehues SM. Reducing the dose of CT of the paranasal sinuses: potential of an iterative reconstruction algorithm. *Dentomaxillofac Radiol* 2016; 45: 20160127: 20160127. doi: <https://doi.org/10.1259/dmfr.20160127>
- American Association of Physicists in Medicine. The measurement, reporting, and management of radiation dose in CT AAPM Report No. 96. College Park, MD: AAPM; 2008.
- <https://www.radiologysolutions.bayer.com/products/ct/dosemanagement/rep/>. Updated June 2016. [Accessed June 29, 2016].
- Chaparian A, Tavakoli I, Karimi V, doses O. effective dose, and radiation risk assessment in radiography of pediatric paranasal sinuses (Waters view). *Asian Biomedicine* 2013; 7: 695–8.
- Schell B, Bauer RW, Lehnert T, Kerl JM, Hambek M, May A, et al. Low-dose computed tomography of the paranasal sinus and facial skull using a high-pitch dual-source system—first clinical results. *Eur Radiol* 2011; 21: 107–12. doi: <https://doi.org/10.1007/s00330-010-1892-6>
- Nievelstein RA, van Dam IM, van der Molen AJ. Multidetector CT in children: current concepts and dose reduction strategies. *Pediatr Radiol* 2010; 40: 1324–44. doi: <https://doi.org/10.1007/s00247-010-1714-7>
- Podberesky DJ, Angel E, Yoshizumi TT, Toncheva G, Salisbury SR, Brody AS, et al. Comparison of radiation dose estimates and scan performance in pediatric high-resolution thoracic CT for volumetric 320-detector row, helical 64-detector row, and noncontiguous axial scan acquisitions. *Acad Radiol* 2013; 20: 1152–61. doi: <https://doi.org/10.1016/j.acra.2013.05.013>
- Aksoy EA, Özden SU, Karaarslan E, Ünal ÖF, Tanyeri H. Reliability of high-pitch ultra-low-dose paranasal sinus computed tomography for evaluating paranasal sinus anatomy and sinus disease. *J Craniofac Surg* 2014; 25: 1801–4. doi: <https://doi.org/10.1097/SCS.0000000000000966>
- Lell MM, May MS, Brand M, Eller A, Buder T, Hofmann E, et al. Imaging the Paranasal Region with a Third-Generation Dual-Source CT and the Effect of Tin Filtration on Image Quality and Radiation Dose. *AJNR Am J Neuroradiol* 2015; 36: 1225–30. doi: <https://doi.org/10.3174/ajnr.A4270>