HOW CAN RADIATION DOSE BE REDUCED TO THE LENS OF THE EYE IN PATIENTS UNDERGOING CT OF THE PARANASAL SINUSES WITHOUT COMPROMISING THE IMAGE QUALITY?

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1. Introduction

1.1 Objective:

It was aim to review the different studies describing the method of reducing the radiation dose to the lens of the eye, during CT of the sinuses without compromising image quality.

1.2 Background:

The CT of the paranasal sinus is a common examination, primarily performed in patients with chronic inflammatory disease or other pathological condition (Yousem, 1993). Development of functional endoscopic sinus surgery (FESS) enhanced the importance of CT paranasal sinuses as it is a minimally invasive way of treating sinus disease (Winzelberg et al.,1993). Therefore, for FESS thin sections are required for the visualization of small pathologies, which results in increased radiation dose to the patient. The most radiosensitive organ encompassed by the scanning field is eye lens, which is at the risk for a radiation-induced cataract (Hein et al., 2002). Therefore, the eye lenses are at certain risk, when the paranasal sinuses are scanned and the radiation effect is thought to be deterministic (McLennan et al., 1995). A threshold of 0.5-2 Gy for detectable lens opacities and a threshold of 4-5 Gy for visual impairment with lens opacification (cataract) have been reported (Dammann et al., 2000). Preexisting damage of the lens further predispose for radiation induced cataract (Nishizawae et al., 1991). The paediatric patient's eye is especially sensitive to radiation and cumulative radiation exposure of 250 mGy has been documented to cause radiation-induced cataract in children (Hopper et al., 2001). Howerever, it was also documented that the radiation dose to lens of the eye is about 5mGy from a routine paranasal sinuses, which compares favourably to Stammberger et al. (1991) estimate of 5-90mGy and 9.81mGy described by Rowe-Jones et al. (1995). However, all of these doses are considerably lower than the threshold of 0.5-2Gy thought to be important in cataract production.

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The standard protocol of CT of the sinuses described by Lau and Yik (2005) was 120-140 KVp, 170-200 mAs with 0.625-1.2 mm of slice thickness and 0.3 mm of interslice gap. However, this protocol slightly varies with different type of scanners and also due to different local protocols. The total amount of radiation dose to the lens is about 20mGy from the standard CT of the sinuses (Czechowski et al., 2001). Therefore, it is important to reduce the radiation dose to avoid the harmful deterministic effects of radiation. The use of low mAs, eye lens protection device (bismuth-containing latex shield) and an increased interslice gap were three methods identified in literature for reducing radiation dose to the lens during the CT of the sinuses. The radiation dose to the lens of the eye is largely a function of the mAs setting of the scanner, with a mean dose of 70.3mGy at 475mAs, 17.6mGy at 210mAs and 4.7mGy at 30mAs (Shrimpton et al., 1991). The reducing mAs setting also have the advantage of reducing tube loading and prolonging the life of the X-ray tube (Mafee, 1991). Reid et al., (2003) concluded that a setting of 60 mAs reduces the radiation dose up to 79% (14.1 mGy) to the lens with optimum diagnostic image quality. Brem et al. (2007) also concluded that the lowest radiation dose which still provided diagnostic quality was ≤ 67 effective mAs for osseous structures and ≤ 134 effective mAs for the optic nerve and the inferior rectus muscle. Similarly, Shoaib et al. (2001) also found that the radiation dose can be reduced during CT of sinuses which results in low dose to the lens, with no loss of image quality. Hence, it demonstrated from the published literature that the radiation dose to the lens can be reduced by using the low mAs with optimum image quality.

Unfortunately, image quality deteriorates as the mAs setting are lowered and this must be maintained for accurate diagnosis (Zinreich et al., 1990). Maempel et al. (2003) and found that the radiation dose to lens from standard protocol of CT sinuses (about 14.2-35.1 mGy) was appeared to be with in the normal range. The similar results were found by Bassim et al. (2005) with multislice CT sinus. They suggested that the low dose CT protocol should not be adopted, which results in noisier images. Hence, a conflict was found with the use of low mAs during CT of the sinuses.

Similarly, according to Moulin et al., (1996) an interslice gap of 3–6 mm can also be utilised during paranasal sinus CT scan which will lead to low radiation dose to the patient without affecting the overall image quality. Some studies also showed that the use of lens protection can also results in less amount of radiation dose to the lens of the eye. These studies were first performed on phantom and then on patients. Hein et al. (2002) suggest that the utilisation of a radioprotection of the eye lenses in paranasal CT is a suitable and effective means of reducing the over all radiation dose by 40%. The artifacts in the area of the protective shield were visualized only in the soft tissue window setting, but without disturbing image quality. Similarly, according to Hopper et al. (2001) CT head was performed by using three different types of bismuth-coated latex eye lens shields thicknesses (1T, 2T, and 3T) on a standard head-attenuating phantom. There was no loss of information and overall radiation dose was decreased to the lens of the eye.

Therefore, it is important to reduce the radiation dose to the lens during CT of the sinuses because; the patients are subject to cumulative radiation exposure due to multiple follow up scans. Therefore, the objective of this literature review was to discuss, critically appraise and make sense of the published evidence regarding the use of technique for reducing the radiation dose to the lens during CT of the sinuses, with an appropriate image quality.

2. Method

In order to understand the research question, a clear and comprehensive search strategy was devised according to NHS Centre for Reviews & Dissemination (2001) and applied to this literature review. The patient, intervention, comparison and outcome (PICO) model was utilized (Tab.2.1) in order to determine the leading question. This facilitated the identification of search terms (Tab.2.2) which were then utilized in the search of literature from the following databases, CINAHL, MEDLINE, Pub Med, Science direct, EMBASE and The Cochrane Library.

Table 2.1: PICO format question generation

Population	Patients computed tomography (CT) of the paranasal sinuses
Intervention	Different methods published in the literature for reducing the radiation dose to the lens of the eye
Comparison	The standard protocol technique of CT of the sinuses
Outcome	Low radiation dose to the lens of the eye with out compromising image quality

Table 2.2: Resultant database search terms
The following search terms were identified using PICO model, which were then used to find out the relevant literature

Population	CT sinus, patients, sinusitis, bony abnormality, Paranasal, sinuses, scanning
Intervention	Eye lens, methods, CT sinus strategies, low dose, optimization, dose parameters, reduction, radiation dose, dose lens, protection lens, lowest achievable, effect decreasing mAs, potential. low acquisition, shielding, radiation protection
Comparison	Standard CT sinus, protocol, radiation dose, eye dose lens, recommended dose
Outcome	Image quality, reducing dose lens, decreasing, CT sinus dose, cataract

Table 2.3: Inclusion and Exclusion criteria
The following inclusion and exclusion criteria were applied to the studies.

Inclusion	Exclusion
CT sinus examinations describing the method of reducing radiation dose to the lens of the eye, without dis-turbing image quality. The studies were also included if they were performed on lens of the eye with any other body organ.	The methods of reducing the radiation dose to other organs during the CT of the paranasal sinuses (like thyroid).
Human and phantom studies because most of the relevant studies found were performed on both.	The medical imaging examination other than CT.

No exclusion was made on the basis of age, sex and year of publication.

3. Results

All databases were searched using the PICO search terms stated in (Tab.2.2). The result from the best combination of search terms from each database was used and the number of these studies identified described in the following table:

Table 3.1: Database Search Results Totals

Databases	No. of Studies Found
CINAHL	63
Medline	74
PubMed	3
EMBASE	200
The Cochrane Library	9
Science direct	236
Total	**585**

The total results from all databases were then compared, duplicates removed and remaining studies collated. A flow chart of identifying the relevant studies purposed by McDaid et al. (2005) was used to obtain the relevant studies for the review (see appendix II). A total of 577 out of 585 were identified as irrelevant and excluded, leaving with 8 relevant studies.

4. Critical Appraisal

All the studies were appraised using the Critical Appraisal Skills Programme (CASP) healthcare research appraisal tools. This enabled for the relevance, validity, reliability and generalizability of all studies included in this review. The CASP appraisal tool was applied to all 8 studies of different study designs (see appendix IV) and was utilized to highlight the strengths, weaknesses and limitations of all the studies.

A CASP tool consisted of 10-13 different questions depending upon the type of the study, enable individuals to develop the skills to find and make sense of research evidence, helping them to put knowledge into practice (NHS Public Health Resource Unit, 2007). This facilitated a comparison of all the studies results and conclusions whilst demonstrating an insight into the individual evidence's relative worth with respect to the concurring or conflicting data from compared studies within this literature review (Aveyard 2007:76-85).

The CASP appraisal tool of 8 studies is as follow:

Author/Date	Aim of Study	Type of Study	Conclusion	Strengths/limitations
1) Brem et al (2007)	Multidetector CT of the paranasal Sinus: Potential for Radiation Dose Reduction	Cohort retrospective	The tube current can lowered and radiation dose to the lens of the eye can be reduced up to 20% without compromising image quality	1. A small sample was selected (n= 40) for the study 2. There was also no evidence of randomization in their study 3. The retrospective study utilised less time but contain more chance of bias as compare to prospective
2) Shoaib et al (2001)	It was aim to determine the effect of decreasing mAs on image quality and patient dose in sinus CT	Case control	The mean radiation dose was reduced by 77% at 50 mAs with out loss of diagnostic image quality	1. A small sample size was considered (n=40) with 10 in each group 2. There was also no evidence of randomization in selecting the patients. 3. The study design was appropriate with one control group. The case control studies are less susceptible to bias as compare to other observational studies

3) Hein et al (2002)	It was aim to determine the low dose CT of the paranasal sinuses with eye lens protection: effect on image quality and radiation dose	Cohort prospective	The utilisation of a radioprotection to the lens of the eye in paranasal sinuses is suitable and effective way reducing the radiation dose by 40%	1. A large sample size was considered (n= 127) for the study which is important for the generalisability of the study 2. The patients were randomly selected for study. However, it was not shown which statistical tool was utilised to determine the results.
4) Moulin et al (1996)	It was aim to determine the radiation dose to the lenses in CT of the paranasal sinuses	Cohort prospective	The radiation dose to the lens of the eye directly depends upon the number of axial sections and can be reduced by using interslice gap	1. A very small sample size was utilised in the study (n= 20) but, the cohorts were in acceptable way 2. A test of parametric correlation was used which is a powerful statistical tool for comparing the two groups 3. there was evidence of any possible limitation
5) Marmolya et al (1991)	It was aim to discuss the methods of analysis and advantages to using low mAs settings at CT of the paranasal sinuses	Cohort prospective	The low mAs protocol can be adopted for CT of the paranasal sinuses with out compromising image quality	1. The sample size was appropriate (n= 90) and the cohorts were also selected in an appropriate way 2. The patients were selected randomly for the study
6) Reid et al (1998)	To determine optimum CT scan protocols for patients undergoing prefunctional endoscopic sinus surgery (FESS) imaging, so that the radiation dose can be reduced to the lens of the eye.	Randomised control trial	Scans of diagnostic quality can be achieved in patients requiring pre-FESS imaging, at considerable dose reduction, by using mAs values lower than those recommended by the manufacturers.	1. An acceptable amount of patients were selected for the (n=60) and study clearly ask the focussed question 2. The study design was appropriate because the patients were randomly allocated for low dose CT protocol and standard protocol 3. The patients were allocated randomly in both groups. 4. The viewers were remain blinded to control the review bias.
7) Maempel et al (2003)	It was aim to determine the radiation dose to the lens of eye and thyroid during coronal and axial sections during CT of the sinuses and then reducing the radiation dose up to 120 and 40 mAs with only axial scanning to determine radiation dose to the lens and affect on image quality	Cohort prospective	The radiation dose to the lens of the eye was high in coronal plane as compared to axial and the dose from the 120 and 40 mAs scan was less than the limit of causing any visual impairment. However, image quality remains optimum in both these scans.	1. The total 57 were randomly selected (28 for coronal and 29 for axial). However, a slightly large sample size was required. 2. It was difficult to understand that how the image quality was assessed and what possible scores were given to each image 3. Stratified random sampling was utilised in selecting the patients.
8) Kearney et al (1997)	It was aim to determine the effect of reducing mAs (at 40 mAs and 60 mAs) on the image quality and radiation dose to the lens of the eye during CT of sinuses	Cohort prospective	There is a potential of reducing the tube current up to 40 mAs which results in low dose to the lens of the eye with out affecting image quality	1. A small sample size (n=20) was considered with 10 in each group. 2. A student t test was utilised with the use of image quality scoring system to categorize the images of both cohort.

5. Discussion

There were three different methods identified from the literature for reducing the radiation dose to the lens of the eye without compromising image quality during the CT of the sinuses (Tab.5.1).

Methods	Authors
Use of low mAs technique	Marmolya et al. (1991), Kearney et al. (1997), Reid et al. (1998), Shoaib et al. (2001), and Brem et al. (2007). Disagreed: Maempel et al. (2003)
Use of bismuth containing latex Shield	Hein et al. (2002) Disagreed: No study found
Use of increased interslice gap	Moulin et al. (1996) Disagreed:

5.1 Use of Low mAs Technique

The mAs actively participate in providing radiation dose to the patient. Therefore, low mAs should be utilised during CT sinuses which resulted in low dose to the lens of the eye (Philip, 2001). There is a potential of reducing the dose during CT sinus because, high contrast tissues namely air, soft tissue and bone are being scanned (Tack et al, 2003).

The 5 out of 8 studies were found highlighting the significance of using low mAs. These studies showed that the radiation dose to lens of the eye can be reduced by using low mAs without reducing image quality. A cohort prospective study was conducted by Marmolya et al. (1991) to analyze the methods and advantages of using low dose CT of the sinuses. They performed the axial and coronal low dose CT (16 mAs for axial and 23 mAs for coronal) techniques on the head phantom and determine the radiation dose by using TLD (thermoluminescent device). They found a radiation dose reduction to the lens of the eye by using the low scanning technique. Hence, they showed that there is a potential for reducing the radiation dose with adequate image quality with acceptable change in noise (Fig.5.1). The same systematic dose reduction was then used in patients (n=90), who were randomly selected for CT sinus. Their results were similar to the phantom study and they suggested that a low dose CT sinus protocol should be adopted. This initial study was pivotal and inspired further studies within the medical and scientific communities due to the invent of advanced CT scanners with coronal and saggital reconstructions. The limitation of this study was that the images were slightly noisier towards the bony structures. However, this limitation was common to almost all studies suggesting low dose technique, included in this review.

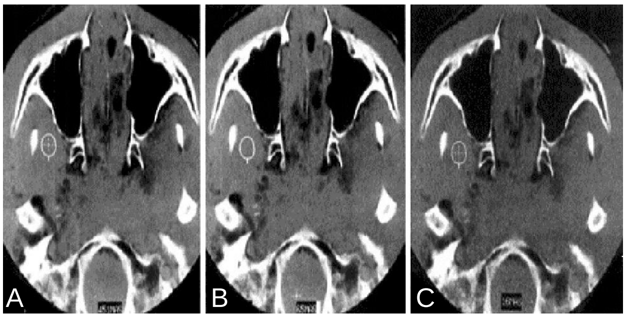

Figure 5.1: Axial CT images through the maxillary sinuses of a head phantom show acceptable changes in noise with decreases in milliampere second settings: (A) 451 mAs, (B) 65 mAs and (C) 16 mAs.

A randomized control trial (RCT) was performed by Reid et al. (1998) on 60 consecutive patients following head phantom dosimetery experiments with variety of mAs on two different scanners (Siemens Somatom and GE pace). They randomly assigned the patients for the current department protocol and a low dose protocol. The radiation dose to the eye was measured in both groups by using TLD. The radiologists were blinded to scan protocol, when scoring images. This is an important activity in RCT, because it reduces the reviewer bias and other confounding factors (John et al., 2007). The scores were then compared using a two sample t test. The t test for two independent groups is probably the most widely used statistical test. It is simple, straightforward, easy to use, and adaptable to a broad range of situations (Lorry, 1999). The result of this study was similar to the earlier study conducted by Kearney et al. (1997). They found a radiation dose reduction to the lens up to 28 % (11.4 mGy) at 100 mAs as compare to 15 mGy at 140 mAs by using Siemens Somatom scanner. Similarly, radiation dose to the lens by using low dose protocol on GE pace scanner was reduced by 79% (14.1 mGy) at 60 mAs as compare to 64.8 mGy at 260 mAs. They also showed that it was not associated with any subjective or objective loss of the image quality for the important anatomical structures.

This RCT study encouraged Shoaib et al. (2001) to conduct a prospective case control study from June to August 2000. There study design was appropriate because their aim was to compare the low acquisition technique (intervention) with the standard one (control group). After taking the consent, 40 patients (with 47 mean age) were recruited and divided equally, into four groups (n=10 in each group). There was no evidence of randomization in their study which is important to reduce the selection bias (Berger, 2005). The first group was scanned using 200 mAs (standard protocol at their respective hospital) and in the rest of the subsequent groups, the mAs were progressively reduced to 150 mAs, 100 mAs and 50 mAs, respectively. The image quality was assessed by using the EC quality criteria for computed tomography (1998). Statistical analysis was performed using the SPSS (v 6.1.3) software package with significance taken as p<0.05. The mean radiation dose was reduced at 150 mAs, 100 mAs and 50 mAs by 43%, 54% and 77%, respectively as compared to radiation dose at 200 mAs. On the basis of their results, they suggested that low mAs directly reduce the dose to the lens of the eye. Similarly, according to scoring system, images maintain their diagnostic quality at 50 mAs (Fig.5.2). However, the images obtained at 50 mAs were slightly noisier towards the high contrast (i.e. bony) detail. Therefore, this may mimic any underlying bony pathology or abnormality.

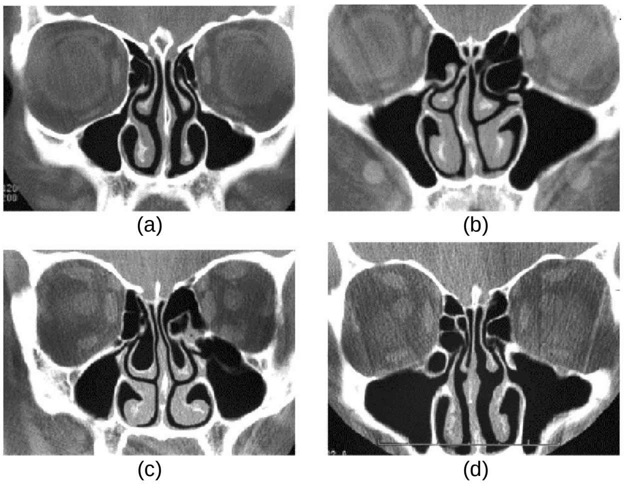

Figure 5.2: Coronal CT of the sinuses at the four different mAs settings: (a) 200 mAs, (B) 150 mAs, (C) 100 mAs and (D) 50 mAs

Similarly, Brem et al. (2007) also published their results of a retrospective cohort study, which were in accordance with all the study of T discussed above. About 40 consecutive images were obtained from March 2003. The Artificial image noise was added to the original data acquisition at 80%, 60%, 40%, and 20% of the original tube current setting, which corresponds to 134, 100, 67, and 33 effective mAs, respectively. The readers were asked to grade the image quality for bone and soft tissue structures by using a five-point scale. Student t tests were used to assess for a significant difference in the mean ratings of observers. A Pair-wise comparison of the ordinal rating data between the readers and among different settings was performed by using the Fisher exact test. The radiation dose that still provided diagnostic quality was ≤ 67 effective mAs for osseous structures and ≤ 134 effective mAs for the optic nerve and the inferior rectus muscle (Fig.5.3). They also suggested that the there is a potential of reducing the radiation dose to the lens of the eye by utilising the using this technique. The computer simulation of low-dose scan acquisition was used to add the image noise to the original data acquisition. This may serve as a useful tool to determine the image quality at the different mAs without radiating the patients.

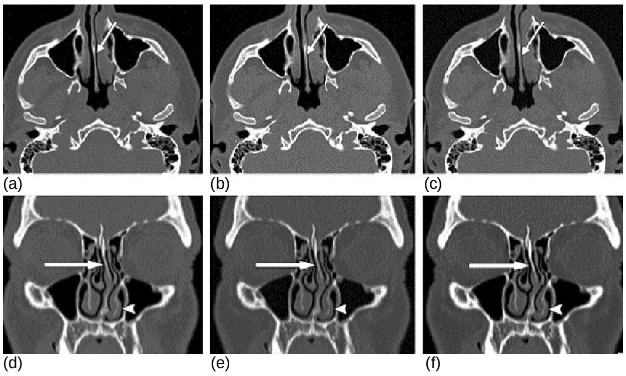

Figure 5.3: Multidetector CT scans of paranasal sinus in a patient with deviation of nasal septem. Data reconstruction with bone algorithin. (a-c) Transverse 1.25-mm sections and (d-f) conronal multiplanar reformations. (a,d) Original acquisition at 170 effective mAs is compared with simulated tube current reduction to (b,e) 80% and (c,f) 60% of the original tube current. The nasal septum (arrow) and inferior turbinate (arrowhead) are clearly delineated.

However, Maempel et al. (2003)) found no significant difference between the doses from low CT sinus protocol (40 mAs) and multislice standard CT protocol to the lens (10 mGy at low dose CT and 14.2-35.1 mGy at standard). They concluded that the doses are below the threshold for lens damage from the standard

CT protocol and during a period of years, a dose between 6 and 14 Gy is required for cataract formation. This is equivalent to atleast 200 CT scans with the standard protocol, far more than any patient is likely to receive. Therefore, from their results they suggested that the low mAs results in slightly noisier images and therefore, high mAs are required when assessing complications of sinus disease. Later, there results were supported by Basim et al. (2005) who found the dose from high-resolution CT of the sinus was lower than the reported acute thresholds of 2 Gy for lens opacities.

5.2 Use of Bismuth-containing latex shield: In the published literature, there was another method found for reducing the radiation dose to the eye which was by using bismuth-containing latex shield (Fig.5.4).

Figure 5.4: Use of bismuth-containing latex shield, from the study conducted by Hein et al.

In 2002, Hein et al. found that the utilisation of radioprotective eye lens device during paranasal CT reduced the radiation dose by 40%. Firstly, they measured the radiation dose and artefact with an eye lens protection placed on a head phantom. A bismuth-coated latex shield containing heavy metal bismuth (equivalent to 0.45 mg/cm3 lead) was used. Afterward, they considered a large sample size of 127 patients for their study. The image quality and radiation dose were assessed in both cases and they found that the effect of eye shielding in decreasing radiation dose was highly significant.

There were some limitations of using this technique such as evaluation of quantitative assessment of CT density in the area close to the protective shield, e.g., the orbital as for insistence head CT (brain perfusion studies) or tumour assessment. This was an acceptable drawback since the shield reduce dose to the lens of the eye.

5.3 Use of increased interslice gap:

A prospective cohort study was conducted by Moulin et al. (1996) which supported the use of an increased interslice gap (up to 6mm) which reduces the number of slices and radiation dose to the lens of the eye without affecting image quality. A CT of the paranasal sinuses was performed in 20 patients for the assessment of ethmoidonasal polyposis. The patients were divided in two groups (10 in each group). They considered a very small sample size with no evidence of randomization in selecting the patients.

In one group, the axial and coronal sections were obtained with an interslice gap of 6mm and 5mm, respectively. In the other group the bidimentional reconstruction was used with 2.5 mm slices and with an overlap of 0.5 mm with coronal and sagittal sections by reconstruction. The radiation dose was measured using TLD. A test of parametric correlation was used which is a strong statistical tool when comparing the two groups (Ninness et al., 2002).

According to the results of the study, the mean radiation was 22 mGy for the patients who underwent CT with increased interslice gap and 42 mGy with bidimentional reconstruction ($P<10^{-5}$). However, there was a significant relationship found between the radiation dose and the total number of slice ($r= 0.7$; $p= 0.0005$). They suggested that technique with using an increased interslice gap reduced the overall radiation dose to the lens, with an optimum diagnostic image quality. However, series of thin overlapping slices are important for FESS and hence bidimentional CT may be required.

5.4 Quality of evidence:

The studies found from different hierarchy levels provided enough information and evidence to answer the proposed question of this literature review. Most of the studies found were observational studies and there was only one RCT. However, there no reported case related to the radiation induced cataract was found, due to the utilization of CT of the sinuses which was important to support this review.

A limitation to generalizability was found in studies discussing the use of low mAs. The results of these studies were not directly applicable to other scanners because the same tube current settings result in different patient radiation exposure with scanners of different manufactures (Shoaib et al., 2001 and Brem et al., 2007). Similarly, in most of these studies a small sample size was considered.

However, only two studies (case control and cohort prospective) were found supporting the use of eye lens shielding and used of increased interslice gap. No study was identified which disagreed with the results of these studies.

6. Conclusion

The radiation dose to the lens of the eye during CT of the sinuses can be reduced by using low mAs without compromising image quality. The lowest radiation dose which still provided the optimum image quality was 50 mAs as compared to standard protocol. However, a conflict was found regarding the use of low mAs because, and the researchers concluded that doses are still below threshold for lens damage.

Similarly, one study found supporting the use of eye lens protection device during CT of the sinuses. According to it, the utilisation of bismuth containing latex shield for the lens in paranasal CT is an effective way of reducing radiation dose by 40% and there was no information loss on the images. There was also one study found which suggested the use of interslice gap which reduces the radiation dose to the lens of the eye.

7. Limitations of the review

Most of the studies found were suggesting the use of lens shielding during CT head. Similarly, some studies found describing the methods for reducing radiation dose to thyroid during the CT of sinuses. All these studies were not included as these were not within the scope of this review. Some relevant studies found were in non-English language and therefore, excluded from the review. This resulted in less number of studies. Similarly, the studies included in the literature review were gathered from the databases and sources described above and studies on databases which were not available, were not included. Therefore, this makes the evidence insufficient to support this review and hence, it made difficult to recommend the most effective method for reducing the radiation dose to lens of the eye during CT sinus with an adequate image quality.

8. Recommendations

A persistent high exposure to the lens of the eye from a standard protocol of CT of the sinuses would lead to cataract (Gordon et al., 2000). There are many parameters such as collimation, pitch and gantry cycle time which influences the patient radiation dose during CT (Rothenberg and Pentlow, 1992). Similarly, according to Kalra et al. (2004) an increase in the pitch and gantry rotation decreases the duration of radiation exposure to the anatomic part being scanned. Therefore, these are the important technical parameters but, no study was found which explained the influence of these parameters on the radiation dose to lens during CT of the sinuses.

Therefore, on basis of this literature review, it is recommended that a research should be directed towards defining and achieving high image quality, technology-based methods and modulation of the relevant parameters to achieve a diagnostic quality CT sinus images at a minimal dose (Aweds and Arogundade, 2007). This will influence the general practice and will results in low radiation dose to the lens during CT of the sinuses without compromising image quality.

References

1. Aveyard H (2007) Doing a Literature Review in Health and Social Care: A Practical Guide. Maidenhead: McGraw Hill.

2. Aweda, M and Arogundade, R (2007) Patient dose reduction methods in computerized tomography procedures: A review. International Journal of Physical Sciences. **2(1):** 1-9.

3. Bassim, K., Ebert, C., Sit, R and Senior, B Radiation Dose to the Eyes and Parotids During CT of the Sinuses. Otolaryngology - Head and Neck Surgery. **133(4):** 531-3.

4. Berger, V (2005) Selection Bias and Covariate Imbalances in Randomized Clinical Trials. New York: Wiley

5. Brem, M., Zamani, A., Riva, R., Zou, K., Rumboldt, Z., Hennig, F., Kikinis, R., Norbash, A. and Schoepf, U (2007) Multidetector CT of the Paranasal Sinus: Potential for Radiation Dose Reduction. Radiology, **243(3):** 847-52

6. Czechowski, J., Janeczek, J. and Kelly G. (2001) Radiation dose to the lens in sequential and spiral CT of the facial bones and sinuses. Eur. Radiolo. **11(2):** 711-3.

7. Dammann, F., Momino-Traserra, E and Remy, C (2000) Radiation exposure during spiral-CT of the paranasal sinuses. Fortschr Röntgenstr. **172(3):** 232-7.

8. Gordon, K., Char, D and Sagerman, R (2000) Late effects of radiation on the eye and ocular adnexa. International Journal of Radiation Oncology. **31(5):** 1123-39.

9. Hein, E., Rogalla, P., Klingebiel, R and Hamm B (2002) Low-dose CT of the paranasal sinuses with eye lens protection: effect on image quality and radiation dose. Eur Radiol **12(2):** 1693-6.

10. Hopper, K., Loel, D and Steven., K. (2001) Radioprotection of the eye during the CT scanning. Am J Neuroradiol **22:** 1194-8.

11. John, I., Gallin, F and Ognibene, P (2007) Principles and practice of clinical research. 2nd ed. New York: Elsevier

12. Kalra, M., Michael, M., Maher, D., Thomas, L., Toth, D., Leena, M., Hamberg, J., Michael A., Blake, M., Shepard, J and Sanjay, S (2004) Strategies for CT Radiation Dose Optimization. Radiology **230:** 619-28

13. Kearney S., Jones, P., Meakin, K and Garvey, C. (1997) CT scanning of the paranasal sinuses- effect of reducing mAs. BJR, **70:** 1071-4.

14. Lau, K and Yik, T (2005) CT Standard Protocols [online]. Available from: http://svc044.wic008tv.server-web.com/imaging/ protocols/ct_protocols_2005.pdf [assessed on 22nd April 2010].

15. Lowry R (1999) t-Test for the Significance of the Difference between the Means of Two Independent Samples [online]. Available from: http://faculty.vassar.edu/lowry/ch11pt1.html [assessed on 30th April 2010].

16. Maempel, Z. (2003) Radiation dose to the lens of eye and thyroid gland in paranasal sinuses mutislice. BJR, **76:** 418-20

17. Marmolya, G., Ernest, J., Rauf, Y., Chandra, D., Haria, A and Shah, C. (1991) Paranasal Sinuses: Low-Dose CT. Radiology, **181:** 689-91.

18. Mafee, M (1991) Endoscopic sinus surgery: role of the radiologist. Am J Neuroradiol.**12:** 855-66.

19. Moulin, G., Chagnaud, C., Wauitier, S., Brigand, B., Chatenet, P and Botti, G. (1996) Radiation dose to the lenses in CT of the paranasal sinuses Neuroradiology **38:** 127-9.

20. McDaid, C., Hartley, S., Bagnall, A., Ritchie, G., Light, K and Riemsma R (2005) Systematic review of effectiveness of different treatments for childhood retinoblastoma. Health Technol Assess **9:** 1-145.

21. Nishizawa, K., Maruyama, T., Takayama, M., Okada, M., Hachiya, J and Furuya, Y (1991) Determination of organ dose equivalents from computed tomographic examination. BJR **64:** 20-8.

22. Ninness, C., Newton, R., Saxon, J and Rumph, R (2002) Small group statistics: A Monte Carlo comparison of parametric and randomization tests. Behaviour and Social Issues. **12:** 53-63.

23. NHS Centre for Reviews & Dissemination (2001) Undertaking systematic reviews of effectiveness: CRD guidance for those carrying out or commissioning reviews. CRD Report 4. 2nd ed. York: NHS Centre for Reviews & Dissemination

24. NHS Public Health Resource Unit (2007) Critical Appraisal Skills Programme [online]. Oxford: NHS. Available from: http://www.phru.nhs.uk/Pages/PHD/CASP.htm [assessed on 30th April 2010].

25. Phillips, D (2001) Screening Sinus CT and Paranasal Sinus Imaging. Applied Radiology. **30(5):** 151-4.

26. Rowe-Jones, J., Mackay, I and Colquhon I (1991) Charing Cross CT protocol for endoscopic sinus surgery. J Laryngol Otol **109:** 1057-60.

27. Rothenberg, L and Pentlow, K (1992) Radiation Dose in CT Radiographics **12:** 1225-43.

28. Stammberger, H (1991) Functional Endoscopic Sinus Surgery. Philadelphia: BC Decca.

29. Shrimpton, P., Jones, D and Hillier, C (1991) Survey of CT practice in the UK. Part Dosimetric aspects. NRPB Report R249. London HMSO

30. Sohaib, S., peppercorn, P., Horrocks, J., Keene, J., Kenyon, K and Reznek R. (2001) The effect of decreasing mAs on image quality and patient dose in sinus CT. BJR, **74(2):** 157-61.

31. Tack, D., Widelec, J., Maertelaer, V., Bailly, S., Delcour, C and Gevenois, P. (2003) Comparison Between Low-Dose and Standard-Dose Multidetector CT in Patients with Suspected Chronic Sinusitis AJR **181(2):** 939-44.

32. Winzelberg, G., Hara, K and May, M (1993) Radiology of the paranasal sinuses. In Endoscopic Sinus Surgery. New York: Thieme Medical

33. Yousem, D (1993) Imaging of sinonasal inflammatory disease. Radiology. **188:** 303-4.

34. Zinreich, S., Kennedy, W and Rosenbaum J (1990) Panranasal sinuses, CT imaging requirements for endoscpoic surgery. Radiology.**163:** 769-75.