RESEARCH ARTICLE

Nasal endoscopy: an adjunct to patient selection for preoperative low-dose CT examination in chronic rhinosinusitis

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Objectives: The growing awareness of increased X-ray exposure to the public has led to the propagation of several methods for reducing the radiation dose during CT examination. Low-dose CT protocols do not, however, have an established role in pre-operative evaluation. The aim of this article was to assess the usefulness of nasal endoscopy in the selection of patients under pre-operative care for low-dose CT examination.

Methods: A cadaver head was used to discover institutional minimum acceptable CT image quality and scanning settings. Then, 134 adult patients with chronic rhinosinusitis (CRS) were enrolled into the study and divided randomly into standard dose (120 kVp, 100 mAs) or low-dose CT groups (120 kVp, 45 mAs). Subjective assessment of the diagnostic image quality of the surgically relevant anatomical structures was compared using a five-point scale (from excellent to unacceptable) by a radiologist and sinus surgeon independently. Pathologic states of the nose were quantified according to the Lund–Kennedy endoscopic system (LKES) and Lildholdt's scale.

Results: Image quality was similar in low-dose and standard dose groups in patients without polyps. The quality of 13% of scans from patients with polyps from the low-dose group and 4% from the standard dose group was in the range from moderate to poor. The quality of scans obtained with low milliamperes second (mAs) values worsened in patients with polyps in the middle meatus, but the difference was particularly pronounced compared with standard dose among subjects with Lildholdt's score above 2 ($p < 0.001$). Correlation with LKES revealed that changes other than polyps (*i.e.* discharge, oedema, scarring or crusting) in the nasal cavity alone do not affect the image quality. Interobserver agreement in both groups was very high.

Conclusions: Low-dose scanning should be promoted as the screening imaging method of choice in patients with suspected CRS. Furthermore, low mAs value examination can be performed pre-operatively without fear of significant image quality deterioration in uncomplicated CRS patients without polyps, or with minor changes in nasal endoscopy. Standard dose CT, which provides a better identification of bony landmarks, minimizes diagnostic errors and risk to patients, so it might be considered in those with polyps below the middle turbinate.

Dentomaxillofacial Radiology (2016) **45**, 20160173. doi: [10.1259/dmfr.20160173](https://doi.org/10.1259/dmfr.20160173)

Cite this article as: Fraczek M, Guzinski M, Morawska-Kochman M, Nelke KH, Krecicki T. Nasal endoscopy: an adjunct to patient selection for preoperative low-dose CT examination in chronic rhinosinusitis. *Dentomaxillofac Radiol* 2016; **45**: 20160173.

Keywords: chronic rhinosinusitis; nasal endoscopy; low-dose CT; radiation

Introduction

CT and nasal endoscopy have both become invaluable for the diagnosis of chronic rhinosinusitis (CRS). CT provides detailed and informative images of the sinuses and physicians have come to rely extensively on its findings, meaning that the number of CT procedures has continued to increase.¹ While nasal endoscopy is completely safe, CT is associated with exposing the patient to harmful radiation. In light of the growing awareness among the general public of increased X-ray exposure, several attempts have been made to achieve diagnostic quality images at a minimal dose.^{2,3} As a result, in many institutions, dose reduction protocols replacing the settings recommended by CT manufacturers are used in everyday practice when sinusitis is the clinical question at issue. Although low-dose and ultra low-dose protocols have an undisputed position as a screening method for the detection of inflammation within sinuses, their role as pre-operative examination tools defining bone landmarks in order to avoid complications is still under discussion. The delineation of bone structures necessary for surgeons before operations is widely believed to require higher radiation doses.⁴ Therefore, it is not surprising that some authors recommend the use of only standard dose settings for pre-operative planning and post-operative controls.⁵ This is due to the fact that insufficient attempts have been made to date to individually adapt the dose to the clinical indication and the patient constitution.⁶ Thus, the question remains unanswered as to under which conditions a doctor can request the pre-operative low-dose protocol formulated in the given institution in a patient with CRS. The answer to this question requires the consideration of a number of previously not extensively analyzed factors. The purpose of the present study was to discover whether nasal endoscopy can help individualize scanning protocols.

Methods and materials

Assessment of minimum acceptable image quality

First, in order to determine the institutional minimum acceptable image quality, a human cadaver head was examined on a GE Discovery 750 HD CT scanner (General Electric Healthcare, Milwaukee, WI) with different milliamperes second (mAs) settings (from 100 to 10 mAs). Non-contrast-enhanced helical CT scanning was performed in axial sections covering the region from the top of the frontal sinuses to the hard palate and from the tip of the nose to the region posterior to the clivus. The image quality was evaluated separately by an experienced radiologist and otolaryngologist. Using a 5-point subjective scale [(5—excellent image quality, 4—good, 3—moderate (some artefacts), 2—poor (many artefacts) and 1—unacceptable)], the surgically relevant anatomical landmarks were assessed: the course

of the anterior branch of the ethmoidal artery, the course of the optical nerve next to the sphenoid sinus, canalis infraorbitalis, olfactory fossa and lamina papyracea. These ratings were used to calculate three factors: the radiologist average image quality (RAD), the otolaryngologist average image quality (ENT) and the overall image quality (OIQ), which was the average of the first two values. Each value ranged from 1 to 5.

Patient selection

A cross-sectional, uncontrolled, randomized, single-blind study was conducted on adult patients with symptoms of uncomplicated CRS admitted to the Department of Otolaryngology at Wrocław Medical University. CRS was diagnosed according to previously established rules.⁷ The patients were selected consecutively if they fulfilled the criteria for participation in the prospective study. Paranasal sinus imaging was part of the routine pre-operative clinical assessment. Patients were excluded if they had acute respiratory infections, had used oral or inhaled corticosteroids during the 4 weeks before CT examination or presented with sinus tumours, facial trauma, Wegener's granulomatosis, Kartagener's syndrome, sarcoidosis, cystic fibrosis, immunodeficiency or ciliary dyskinesia. Each of the patients underwent a complete ENT assessment including nasal endoscopy. CT scans were scored according to the Lund–MacKay (L–M) staging system, which measures the degree of sinus opacification (ranging from 0 to 24). Patients without bilateral inflammatory changes were excluded. Each patient gave written consent for the CT examination to be performed and to participate in the study. The study protocol was approved by our institutional review board.

Endoscopic appearance scores

Pathologic states of the nose and paranasal sinuses were quantified according to the Lund–Kennedy endoscopic system (LKES) scoring as follows: polyps were graded as absent (0), present in the middle meatus (1) and beyond the middle meatus (2); discharges were graded as not present (0), thin (1) or thick/purulent (2); and oedema, scarring and crusting were each graded as absent (0), mild (1), or severe (2).⁸ The total scores ranged from 0 to 20.

In addition, polyp sizes were rated using Lildholdt's scale (LS), which classifies nasal polyps into four stages: no polyposis (0), polyps only in the middle meatus (1), polyps beneath the lower edges of the middle turbinate (2) and large polyps reaching the lower border of the inferior turbinate (3).⁹ The total scores ranged from 0 to 6.

CT examination

CT examination of all patients was performed on a Discovery™ 750 HD scanner (GE Healthcare,

Milwaukee, WI) Low-dose protocols included parameters formulated on a cadaver head: tube potential 120 kVp, 45 mAs; detector configuration 64×0.625 mm; pitch 1.3; section thickness 0.625; and gantry rotation time 0.4 s. The images were reconstructed with an adaptive statistical iterative reconstruction algorithm using 50% adaptive statistical iterative reconstruction.

In the standard dose group, the following protocol was used: tube potential 120 kVp, 100 mAs; detector configuration 64×0.625 mm; pitch 0.9; section thickness 0.625; and gantry rotation time 0.7 s. All other scanning parameters were the same for both groups. Patients were randomly selected for low-dose or standard dose protocols according to the day of examination. Low-dose was performed on Mondays, Wednesdays and Fridays, whereas standard dose was performed on Tuesdays and Thursdays. During the experiment, participants were blind to the doses.

Subjective evaluation of image quality

Quantitative analysis was performed for each study using certified diagnostic workstations: AW 4.6 (GE Healthcare, Milwaukee, WI). Reviewed images were reconstructed with 0.625 slice thickness and displayed with a window level/width of 2000/350 HU and sharp filter S3. Two researchers, a radiologist (MG) and an ENT specialist (MF) (both with 10 years' experience), evaluated reformatted axial and coronal images of each patient independently and separately in a blind manner. Scans were graded using the same 5-point subjective scale as above. For each patient, the ratings were used to calculate RAD, ENT and OIQ scores as described above.

Estimation of radiation doses

Radiation dose descriptors were derived from the dose report automatically stored in the picture archiving and communication systems. CT dose index volume, dose-length product and scan range were recorded for both the low-dose and standard dose groups. To calculate effective doses (in millisievert), the dose-length product was multiplied by region-specific normalized effective dose conversion coefficient (k) for the head [$k = 0.0023$ mSv/(mGy cm⁻¹)], as proposed by the European Working Group for Guidelines on Quality Criteria in CT.¹⁰

Statistical analysis

Statistical computations were performed using Statistica software package v. 10.0 (StatSoft Inc., Tulsa, USA). The two-sided t -test with independent variables was used as the test of significance for the analysis of image quality. For all analyses, we considered the 95% confidence interval (CI) and 5% significance interval ($p < 0.05$). Interobserver agreement was assessed using the intraclass correlation coefficient (ICC). ICC can be interpreted as follows: 0–0.2 indicates poor agreement; 0.3–0.4 indicates fair agreement; 0.5–0.6 indicates moderate agreement; 0.7–0.8 indicates strong agreement; and >0.8 indicates almost perfect agreement.

Results

Minimum acceptable image quality

There was no significant difference in the image quality scores given by each observer at any of the mAs settings. The interobserver agreement (mean ICC value was 0.899) was almost perfect. Ratings of CT scan quality at the different current settings revealed that the minimum acceptable image quality should exceed a value of 3 (*i.e.* moderate score). Therefore, scanning at 45 mAs and 120 kV was chosen as our low-dose protocol (Table 1).

Clinical data of patients who were studied and radiation doses

Clinical data for the 134 patients enrolled into the low-dose and standard dose groups are shown in Table 2. There were no significant differences between the two groups in terms of patient age, gender distribution, advancement of inflammation in sinuses on CT scans (L–M scale) and endoscopic score according to LS. Pathologic states of the nose and paranasal sinuses (LKES score) were insignificantly better in the low-dose group. There were slightly more patients with a history of sinus surgery in the standard dose group.

The mean value of the effective radiation dose for the standard dose CT protocol was 0.785 mSv, which was 10 times higher than that of the low-dose protocol (0.078 mSv).

Subjective image quality assessment

The OIQ of examinations performed with a standard dose was 3.89 (both the RAD and ENT rating was 3.89). The OIQ in the low-mAs group as well as scores recorded by the RAD and ENT were significantly lower (3.61, 3.66 and 3.56, respectively) ($p < 0.05$). OIQ ranged from 2.71 (below moderate) to 4.72 (better than good) in the standard dose group and from 2.62 (below moderate) to 4.9 (almost excellent) in the low-dose group. The quality of 11 (13%) scans from the low-dose group and 2 (4%) from the standard dose group was rated below moderate level. According to the ENT

Table 1 Scores for subjective image quality from a radiologist [radiologist average image quality (RAD)] and otolaryngologist [otolaryngologist average image quality (ENT)] for each milliamperere second (mAs) setting used in cadaver head CT examination

mAs setting	ENT	RAD	OIQ
105	4.2	4.1	4.2
85	4.0	3.9	4.0
65	3.7	3.7	3.7
55	3.3	3.5	3.4
45	3.0	3.1	3.0
35	2.4	2.6	2.5
25	1.8	1.9	1.8
15	1.6	1.8	1.7

OIQ, overall image quality.

The 5-point scale ranged from 5 (excellent) to 1 (unacceptable image quality).

Table 2 Comparison between patients with chronic rhinosinusitis diagnosed with low-dose or standard dose CT protocols

Patient characteristics	Low-dose protocol (n = 82)	Standard dose protocol (n = 52)
Female/male, n	43/39	29/23
Age, years, mean (SD)	50.2	49.3
DLP (mGycm), mean (SD)	34.10 (6.51)	341.36 (58.62) ^a
Lund–MacKay CT score, mean (SD)	10.27 (6.73)	11.4 (6.02)
Lund–Kennedy endoscopic score, mean (SD)	5.51 (2.39)	6.31 (2.14)
Lildholdt's scale, mean (SD)	1.54 (1.79)	2.08 (1.72)

DLP, dose–length product; SD, standard deviation.

^a $p < 0.001$.

rating, scans with worse than moderate image quality were noted for 20% and 6% of patients in the low-dose and standard dose groups, respectively.

Interobserver agreement in terms of the image quality assessment was very high. The average ICC value was 0.822 with a 95% CI from 0.708 to 0.894 in the standard dose group and 0.817 with a 95% CI from 0.731 to 0.878 in the low-mAs group.

Correlation between image quality and outcomes of endoscopic examination

The results show that patients with LKES score lower than 4 had an OIQ in low-dose group (3.99) similar to the standard dose group (4.0) (Figure 1). With an LKES score between 4 and 7, image quality in low-dose group was significantly worse than that in standard dose group (3.51 vs. 4.0, respectively) ($p < 0.001$); but, only with LKES > 7 did OIQ descend to as low as 3.13 compared with 3.68 in the standard dose group ($p < 0.05$).

Correlation between image quality and polyp size

The LS, which classifies only nasal polyp size, revealed that OIQ among patients without polyps (LS = 0) was similar in low-dose and standard dose CT protocols (3.98 and 4.13, respectively) (Figure 2). In patients with LS = 1–2, low-dose image quality decreased statistically

compared with the standard dose group (3.42 vs 3.87, respectively) ($p < 0.05$). In cases with LS > 2 , image quality deteriorated more in the group examined with low-dose than that in the group examined with standard dose (3.15 vs 3.75, respectively) ($p < 0.001$) (Figure 3). In the low-dose group, OIQ in selected subjects decreased to as low as almost poor level (2.2), according to the ENT rating. Patients without nasal polyps (LS = 0) always had LKES scores below 7.

Discussion

Evaluation of complex anatomical regions such as paranasal sinuses is not possible with the method of reducing radiation dose during CT examination without compromising image quality. In the present study, the image quality for the assessment of selected anatomical landmarks was acceptable with an excellent-to-moderate score in most cases examined with the proposed low-dose CT protocol (120 kVp, 45 mAs). The use of such settings is in agreement with reports on dose reduction, which recommend scanning at 40–65 mAs for screening purposes in patients with suspected CRS.^{3,11,12} Even though the images were noisier, low-dose CT protocols mostly allowed the production of

Figure 1 The correlation between endoscopic findings according to Lund–Kennedy score and the image quality in patients with chronic rhinosinusitis diagnosed with low-dose (low) and standard dose (stand) CT protocols. Statistical image quality deterioration compared with the standard dose examination: * $p < 0.001$, ** $p < 0.05$. ENT, otolaryngologist average image quality; OIQ, overall image quality; RAD, radiologist average image quality.

Figure 2 The correlation between endoscopic findings according to Lildholdt's scale and the image quality in patients with chronic rhinosinusitis diagnosed with low-dose (low) and standard dose (stand) CT protocols. Statistical image quality deterioration compared with the standard dose examination: * $p < 0.001$, ** $p < 0.05$. ENT, otolaryngologist average image quality; OIQ, overall image quality; RAD, radiologist average image quality.

Figure 3 Coronal images of CT scans obtained according to (a) low-dose (120 kVp, 45 mAs) and (b) standard dose protocols (120 kVp, 100 mAs) in patients with chronic rhinosinusitis with nasal polyps: significant image quality deterioration can be seen in the olfactory fossa [arrow in (a)] from low-dose examination. Well-defined bony margins can be seen in the olfactory fossa [arrow in (b)] and lamina papyracea [stars in (b)] from standard dose scanning.

scans at a level guaranteeing acceptable pre-operative evaluation, as assessed by a sinus surgeon. However, in certain patients, the quality of CT scans was in the range from moderate to poor. The number of scans scored worse than moderate was clearly greater in the evaluations performed by the otolaryngologist.

It is to be expected that owing to the ever growing number of CT devices and diagnostic protocols which reduce the radiation dose in various ways, the number of scans where the quality does not satisfy the doctor expectation will increase. As a result, less experienced sinus surgeons may feel unnecessary intraoperative anxiety and the noisy scans might adversely affect the course of the endoscopic surgery. From this perspective, the present outcomes counter the conclusions of other studies, *i.e.* that low-dose protocols enable visualization of the fine osseous structures and can therefore be routinely used before surgery.^{13,14} It can be assumed that those authors did not sufficiently take into account the impact of advanced inflammatory changes on image quality.

Therefore, it seems necessary to choose clinical parameters that could be used to adjust the examination protocol for given patient constitutions. Our study has revealed that the L–M scoring system used for the evaluation of CRS intensity on CT scans correlates to the greatest extent with image quality. This confirms the known fact that the presence of inflammation increases image noise and decreases the value of low-dose CT scans. However, the L–M system cannot help in patient qualification for CT protocols, because it is based solely on CT scans. Similarly, scores based on a patient's own experiences of symptoms and quality-of-life questionnaires which fail to correlate with staging performed with CT are also not reliable for their intended purposes.^{15,16}

In the present article, it has been shown that a source of helpful information to qualify patients to the optimal CT protocol is endoscopic examination. It was discovered that results obtained from both LS and Lund–Kennedy scale correlate significantly with image quality. Particular attention should be paid to patients with polyps beneath the lower edges of the middle turbinate, where image quality in low-dose scanning can decrease even below a moderate level. In contrast, patients

without polyps on nasal endoscopy can be diagnosed with reduced radiation doses without any significant deterioration of CT scan quality. This was confirmed via an evaluation using the Lund–Kennedy scale, where subjects with scores below 7 never had polyps in endoscopic examination. Therefore, the results showed that changes other than polyps (*i.e.* discharge, oedema, scarring or crusting) in the nasal cavity alone do not affect the image quality in low-dose CT scanning.

Both Lund–Kennedy and Lildholdt's methods for the endoscopic staging of pathologic states of the nose used in the study are easy to employ in clinical practice and are reproducible.^{17,18} They are also prevalent among rhinologists. The credible application of these staging systems, however, requires the use of an endoscope during patient examination. It can also be concluded that the results of nasal endoscopy might form an element of radiological surveys providing information about the advancement of sinus disease.

Owing to a lack of sufficient reports on the influence of inflammation on image noise in low-dose CT examinations, the present article is one of the first to complement knowledge in this field. Further studies are necessary to take into account other clinical parameters. The final conclusions are largely affected by the lack of universally accepted standards of suitable image quality of CT examination for specific indications.⁶ The limitation of the present study, which is difficult to eliminate for medicolegal reasons, is that both the compared protocols were tested in two slightly different groups of patients. It would also be worth expanding the sample size in the future.

It should be mentioned here about the CBCT technology, which can be successfully use as a screening tool for inflammation of the paranasal sinuses.^{19,20} The radiation dose for CBCT considering the appropriate field of view ranges from 0.05 to 0.6, which is similar but mostly higher than that presented for low-dose multi-detector CT protocols.^{21,22} It was previously found that OIQ in CBCT is significantly worse than that in standard CT in patients with sinonasal polyposis.²³ This observation may suggest that the results of the present study can be used in qualification to pre-operative CBCT.

Conclusions

In conclusion, CT examination should answer the questions asked, but does not provide all of the possible information that may be required in specific clinical conditions. Thus, low-dose scanning should be promoted as the imaging method of choice for patients with suspected CRS. Furthermore, low-dose examination can be performed pre-operatively without fear of significant image quality deterioration in patients without polyps, or with minor changes in nasal endoscopy. Standard dose CT provides better identification

of bony landmarks, minimizes diagnostic errors and risk to the patients and might therefore be considered in those with polyps below the middle turbinate. Although radiologist concerns regarding increased X-ray exposure to the public should be respected, it is worth remembering that radiation doses from a single standard dose CT examination is within, or below, the estimated annual radiation from natural sources and cosmic radiation.²⁴ The final decision on the selection of diagnostic protocols should be the individual choice of the physician and largely depends on his surgical experience and expectations.

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