RESEARCH ARTICLE

Effective dose reduction using collimation function in digital panoramic radiography and possible clinical implications in dentistry

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Objectives: The primary aim was to evaluate the effective dose for a full size panoramic image and nine different panoramic protocols using collimation. The secondary aim was to estimate possible reduction of effective dose in clinical situations.

Methods Effective dose, according to International Commission on Radiological Protection 2007 was determined for a full size panoramic image and nine different panoramic protocols applying collimation on an anthropomorphic Rando phantom, using metal-oxide semiconductor field-effect transistor dosimeters. The collimation protocols were chosen based on common diagnostic questions. 10 exposures were made for each protocol using a Planmeca ProMax® 2D (Helsinki, Finland). The mean effective doses were calculated according to clinical default exposure settings and compared for all protocols. A retrospective analysis of 252 referrals to a specialist clinic in dentomaxillofacial radiology assessed usability and dose reduction applying nine different collimation protocols, based on possible collimation of panoramic images. Dose reduction was calculated applying collimation feature in comparison to constant use of full size panoramic imaging. Referrals were categorized according to indication for radiographic examination.

Results: Effective dose of a full size panoramic radiograph was 17.6 µSv at 8 mA and 66 kV. The dose reduction for the collimated images compared to a full size panoramic radiograph ranged from 4.5 to 86.9%. Potential total dose reduction in the studied sample was 35% if collimation feature had been applied. In four out of five of the referrals, collimation was possible and in 61% of the referrals the indication for radiographic examination was restricted to the dental alveolar region, reducing the dose by 40.3% compared with a full size panoramic image.

Conclusions: Since the effective dose may be reduced without losing diagnostic information in the area of interest, collimation feature of panoramic imaging should be routinely applied when the diagnostic task allows.

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Introduction

Panoramic imaging has, since it was first commercially manufactured in 1961, become an important radiographic method for several diagnostic purposes and is frequently used in dentistry. The method provides an overview of the dentomaxillofacial region used as a single radiograph or together with other image modalities for more comprehensive examinations. There is no indication for routine screening of new patients in general practice.¹ Prescription of dental radiographic examination is made on individual basis and needs to have justification and be optimized according to international recommendations.²

The effective dose for oral and maxillofacial radiographic examinations increased considerably after the International Commission of Radiographic Protection (ICRP) revised the organ weighting factors in 2007. According to a study by Ludlow *et al*, the change in effective dose due to the change of tissue weighting factors between ICRP, 1990³ and ICRP, 2007² ranged between 231 and 241% when evaluating two different panoramic radiographic devices with CCD sensor technique.⁴ A recent study emphasizes the importance of the clinician's awareness of the increase in absorbed organ dose and effective dose from digital panoramic radiography when applying the ICRP 103 instead of the ICRP 60 recommendations.⁵ Therefore, evaluating and applying dose reduction approach of panoramic radiography, provided diagnostic outcome is the same, is of importance.

Since ionizing radiation risk is cumulative, minimizing the field of view (FOV) should be considered in examining all patients for dose reduction purposes. Using a panoramic collimation feature might contribute to the overall goal of minimizing unnecessary doses to patients in accordance with the as low as reasonably achievable (ALARA) principle. Therefore, the measurement of effective doses for different collimations of the panoramic image and possible clinical application are of interest.

Several modern digital panoramic X-ray units enable the collimation of panoramic images, both in horizontal and vertical directions, aiming to closely relate to the specific diagnostic task and avoid exposure on area where diagnostic information is not of interest. A recent study reported patient dose reduction applying collimated panoramic radiography in vertical direction.⁶ In this study the effect of two different collimator slit heights, 110 and 140 mm, on effective dose was compared in a panoramic system. Considering the differences in exposure time and collimator height for children and adults, the effective doses were 7.7 and 11.4 μ Sv respectively.⁶

To the best of our knowledge, no previous studies have been performed on dosimetry using collimation function with both horizontal and vertical collimation options as well as possible clinical application on

Figure 1 The chosen collimations for panoramic radiographs used to measure effective dose and categorize clinical applicability, PAN 1–PAN 10. PAN 1 = full size, PAN 2 = Upper front, PAN 3 = mandibular teeth, PAN 4 = Unilateral lower mandibular molars, PAN 5 = All teeth, PAN 6 = All teeth and maxillary sinus, PAN 7 = All teeth and mandibular ramus, PAN 8 = maxillary teeth, PAN 9 = maxillary teeth and maxillary sinus, and PAN 10 = Unilateral lower right molars and anterior ramus. The different collimations numbered 1–15 in the panoramic radiograph in the lower part of the figure.

panoramic radiography (Figure 1). Possible applications for the collimation function could be for diagnostic tasks, in which part of the panoramic image is needed. A common clinical situation is when only teeth and alveolar crest are of interest.

The aim of the study was to calculate the effective dose given to an adult patient from full size panoramic radiography and nine different collimation protocols as well as retrospectively assess the possible application of the collimation function using records of radiographic examinations at the Specialist clinic of Image and Functional Odontology, Department of Dental Medicine, Karolinska Institutet.

Methods and materials

Collimation

10 different collimated panoramic images were chosen to represent common diagnostic tasks, namely: PAN 1—full size (collimation 1–15), PAN 2—upper front (collimation 8), PAN 3—mandibular teeth (collimation 12–14), PAN 4—unilateral lower mandibular molars (collimation 12), PAN 5—all teeth (collimation 7–9, 12–14), PAN 6—all teeth and maxillary sinus (collimation 2–4, 7–9, 12–14), PAN 7—all teeth and ramus (collimation 6–10, 11–15), PAN 8—maxillary teeth

(collimation 7–9), PAN 9—maxillary teeth and maxillary sinus (collimation 2–4, 7–9), and PAN 10—unilateral lower mandibular molars and anterior ramus (collimation 7,12). For illustration, see [Figure 1](#).

Dosimetry

Dose measurements were made on an Alderson Rando RAN102 anthropomorphic adult phantom representing an average male with length 175 cm and weight 73.5 kg (Radiation Analogue Dosimetry System; Phantom Laboratory, Salem, NY). The phantom comprised of a natural human skeleton casted inside a soft tissue simulating material to match the attenuation and scattering conditions of the bone, soft tissue and airways of the human head. The phantom composed of ten 2.5 cm thick layers (0–9) with dosimeters inserted in the head and neck organs used for effective dose calculation in the region. Detectors were positioned in the organs as follows: anterior calvarium, midbrain, pituitary fossa, right orbit, right lens, right cheek, right parotid gland, left parotid gland, right mandibular ramus, left mandibular ramus, center cervical spine, left back neck, right mandibular body, left mandibular body, right submandibular gland, left submandibular gland, center sublingual gland, midline thyroid gland, thyroid surface and pharyngeal-esophageal space.

The phantom was fixed at the same position during all exposures, 10 for each collimation. For all dose measurements, a mobile TN-RD-70-W20 metal-oxide semiconductor field-effect transistor (MOSFET) device was used. The device comprised high-sensitivity TN-1002RD-H detectors, a TN-RD-16 reader module, a TN-RD-38 wireless blue tooth transceiver, and TN-RD-75M software (Best Medical Canada; Ottawa, ON, Canada). The MOSFET device was prior to dose measurements positioned and calibrated according to previous studies using a similar setup. The dose measurement uncertainty was calculated as the weighted sum of variances and included the statistical measurement error according to a former study, dosimeter and phantom positioning uncertainties and cable irradiation uncertainties.^{7,8}

The quantity effective dose (E) can be used to compare the patient dose when using different examination techniques. It is defined by a weighted sum of tissue equivalent doses as:

$$\sum_T w_T H_T$$

w_T is the tissue weighting factor for tissue T and $\sum w_T = 1$. The sum is performed over all organs and tissues of the human body considered to be sensitive to the induction of stochastic effects. These w_T values are chosen to represent the contributions of individual organs and tissues to overall radiation detriment from stochastic effects. H_T is the equivalent dose in tissue T. The unit of effective dose is sievert (Sv).³

20 MOSFET dosimeters were placed into the phantom head layers similar with the protocol described by Ludlow *et al* in 2006.⁹ Since the assumption was made that the organ dose for the brain area is low and that the dose in the left eye and orbit is the same as for the contralateral side, those regions were not measured. A Planmeca ProMax® (Planmeca Oy, Helsinki, Finland) was used for image acquisition with exposure parameters at 66 kV and 16 mA. The tube current was set at 16 mA to maximize the exposure level in order to reduce the standard deviation and subsequently improved the reliability of the measurements. The effective dose was then halved in order to get values for the default setting, 8 mA, recommended by the manufacturer. The measured effective doses for a full size panoramic image and nine different collimated panoramic protocols were derived using 2007 International Commission on Radiological Protection (ICRP) recommendations.² In order to increase the accuracy of the dose measurements for each FOV of interest, 10 sequential exposures were made. The mean and standard deviation of effective dose for each panoramic protocol (PAN1–PAN10) was calculated and compared.

Dose area product (DAP) was measured using a KermaX-plus IDP 120–131 HS meter (IBA Dosimetry; Schwarzenbrück; Germany) attached on the C-arm tube head cover on the panoramic radiography device. Two exposures were made for all the segments, PAN 1 to PAN 10, and mean DAP values were calculated.

Possible clinical application

A retrospective analysis was conducted on all referrals during the period 2017-01-01 to 2017-03-31 at the Department of Dental Medicine, Karolinska Institutet, Sweden. Since the dose measurements were made on an adult phantom only adult patients aged ≥ 18 years that had panoramic examination during the time period or had a previous panoramic radiograph taken within 1 year were included. Age and gender of the included patients were registered. The referrals were classified into 9 groups by a radiologist (DB) according to clinical indication for panoramic examination: (1 = implants both pre and post, 2 = temporomandibular joint disorder, 3 = teeth and jawbone (periapical, periodontal, caries), 4 = prior to tooth removal, 5 = postsurgical problem/follow up, 6 = cyst, tumor and bone disease, 7 = infection, 8 = orthognathic surgery/orthodontic treatment, 9 = trauma). Based on the diagnostic questions written in the referrals a classification was made upon possible collimation in the dose assessment protocol, PAN 1–PAN 10. The assessments of possible collimation and protocol ([Figure 1](#)) were performed by the same radiologist (DB).

By summing up assessed collimation for each individual the dose reduction was calculated and presented in percentage compared to constant use of full panoramic images. Furthermore the proportion of each collimation protocol were calculated to give an indication of usability.

In order to evaluate the benefit of using several collimation protocols in clinical practice, the potential reductions in effective dose were estimated for cases with a limited number of available protocols. Nine cases were included, from the 2 protocols with the highest clinical applicability up to all 10 selectable protocols.

Results

Part 1. Dosimetry

In Table 1, the calculated effective dose and DAP for all the evaluated panoramic protocols, PAN 1–PAN 10, are presented as mean and standard deviation. The calculated mean effective doses are: PAN 1 17.6 μ Sv, PAN 2 2.3 μ Sv, PAN 3 7.9 μ Sv, PAN 4 5.0 μ Sv, PAN 5 10.5 μ Sv, PAN 6 11.7 μ Sv, PAN 7 16.8 μ Sv, PAN 8 4.6 μ Sv, PAN 9 4.5 μ Sv, and PAN 10 5.9 μ Sv. For each protocol, the used FOV are presented in accordance with numbered collimations displayed in Figure 1. Furthermore the percentage of effective dose for each collimated protocol, PAN 2–PAN 10 compared with PAN 1 are listed.

The calculated reduction in effective dose using the collimation function in comparison with a full size panoramic image are listed in order of reduction degree: PAN 2 (86.9%), PAN 9 (74.4%), PAN 8 (73.9%), PAN 4 (71.6%), PAN 10 (66.5%), PAN 3 (55.1%), PAN 5 (40.3%), PAN 6 (33.5%). and PAN 7 (4.5%).

The calculated mean dose contribution from exposed organs during 10 repetitions contributing to the total effective dose are listed for each panoramic collimated protocol in Table 2.

Table 1 Description of FOV for each collimated panoramic image (collimations in accordance with Figure 1), mean and standard deviation of effective dose, dose in percentage compared with full size panoramic image, mean and standard deviation of DAP

Panoramic		Percent of full DAP Effective dosesize image		
Protocol ^a	Collimations	(μ Sv)	(%)	(μ Gym ²)
PAN 1	1–15	17.6 $\pm$ 0.8	100	8.3 $\pm$ 0
PAN 2	8	2.3 $\pm$ 0.3	13.1	0.9 $\pm$ 0
PAN 3	12–14	7.9 $\pm$ 0.9	44.9	2.0 $\pm$ 0
PAN 4	12	5.0 $\pm$ 0.5	28.4	0.6 $\pm$ 0
PAN 5	7–9, 12–14	10.5 $\pm$ 0.7	59.7	3.8 $\pm$ 0
PAN 6	2–4, 7–9, 12–14	11.7 $\pm$ 1.0	66.5	5.7 $\pm$ 0
PAN 7	6–15	16.8 $\pm$ 1.2	95.5	5.6 $\pm$ 0.01
PAN 8	7–9	4.6 $\pm$ 0.4	26.1	1.9 $\pm$ 0
PAN 9	2–4, 7–9	4.5 $\pm$ 0.6	25.6	3.7 $\pm$ 0
PAN 10	7, 12	5.9 $\pm$ 0.7	33.5	1.1 $\pm$ 0.01

FOV, field of view; DAP, dose area product.

^aTube voltage 66 kV and tube current 8 mA are constant for all protocols.

Table 2 Mean absorbed organ doses (mGy) for all panoramic protocols with constant 66 kV and 8 mA

Organ	PAN 1	PAN 2	PAN 3	PAN 4	PAN 5	PAN 6	PAN 7	PAN 8	PAN 9	PAN 10
Bone marrow	0.40	0.07	0.23	0.08	0.30	0.29	0.40	0.13	0.12	0.09
Thyroid	0.04	0.01	0.02	0.02	0.03	0.04	0.05	0.02	0.01	0.02
Esophagus	0.05	0.01	0.04	0.02	0.02	0.04	0.05	0.02	0.01	0.02
Skin	0.05	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.01
Bone surface	0.57	0.08	0.08	0.04	0.23	0.22	0.54	0.16	0.15	0.08
Salivary glands	0.89	0.09	0.28	0.19	0.45	0.45	0.86	0.20	0.18	0.25
Brain	0.10	0.01	0.02	0.01	0.02	0.07	0.02	0.01	0.07	0.01
Lymphatic nodes	0.45	0.05	0.15	0.09	0.25	0.25	0.43	0.11	0.10	0.12
Extrathor airways	0.37	0.04	0.13	0.08	0.20	0.21	0.35	0.10	0.08	0.10
Muscle	0.20	0.02	0.14	0.09	0.15	0.17	0.20	0.05	0.04	0.09
Oral mucosa	0.52	0.06	0.17	0.10	0.28	0.28	0.50	0.13	0.12	0.14

Part 2. Clinical assessment

From the total of 295 patients, 252 patients were included according to inclusion criteria. Of the included patients, 69 of them had a panoramic radiograph taken within 1 year prior to the examination. In two cases a panoramic radiograph was taken although there already existed one exposed within 1 year prior to the examination. The mean age of the group of patients were 53 years with the age range of 20–86 years. The referred patients were 62% females ($n = 156$) and 38% males ($n = 96$).

The number of patients and its corresponding percentage for each collimation protocol are displayed in Figure 2. 81% of the patients were examined using either PAN 1 or PAN 5. If also including PAN 3 and PAN 10 93% of the patients in the sample were included. The clinical indication for referral was classified in 10 different subgroups that are presented in number and percentage of patients referred for panoramic examination (Figure 3). In 78% of the referrals ($n = 197$) collimation were considered as possible based on the clinical question in the referrals. A full size panoramic image was considered to be necessary in 22% ($n = 55$) of the referrals. The calculated possible total dose reduction for the studied group was 35% compared with if using full size panoramic protocol (PAN 1) on all referrals regardless of indication.

In Figure 4, the effective dose reductions in the studied sample is displayed, if categorizing the number of selectable collimation protocols from 2 to 10, in order of clinical applicability, compared with if solely using the collimation of OPG 1. The order of clinical applicability is OPG 5, OPG 1, OPG 10, OPG 3, OPG 9, OPG 7, OPG 2, OPG 8, OPG 6, and OPG 4 (Figure 2). Limiting the number of selectable collimation protocols to two, the effective dose reduction is 29.7%. The

Figure 2 Proportion of the possible collimated panoramic images based on referrals.

possible effective dose reduction varies from 31.5 to 35.4% using 3 to 10 selectable collimations protocols.

Discussion

To the best of our knowledge this is the first study that measures the effective dose with MOSFET using the chosen collimation feature in panoramic radiography. Several methods may be applied for estimating effective dose from various radiographic examinations. In previous studies of effective dose assessment the most frequently used technique is thermoluminescent dosimeters (TLDs). The TLDs are placed in allocated phantom head positions, occasionally in pairs. Prior to the reading of the TLDs the head must be dismantled after exposure and the TLDs placed in a TLD oven. Since the present study required multiple effective dose readings, in combination with the object being in fixed position for all exposures, digital dosimeters were preferred. Therefore the MOSFET dosimeters technique using digital dosimeters was considered appropriate for this

Figure 3 Reasons for referral categorized in nine groups. Frequency of referrals in each group.

Figure 4 Dose reduction in percentage calculated based on selectable protocols from 2 to 10 collimation protocols. Protocols were sorted in order of clinical applicability in the studied sample. 2 = PAN: 5 and 1, 3 = PAN: 5, 1 and 10, 4 = PAN: 5, 1, 10 and 3, 5 = PAN: 5, 1, 10, 3 and 9, 6 = PAN: 5, 1, 10, 3, 9 and 7, 7 = PAN: 5, 1, 10, 3, 9, 7 and 2, 8 = PAN: 5, 1, 10, 3, 9, 7, 2 and 8, 9 = PAN: 5, 1, 10, 3, 9, 7, 2, 8 and 6, 10 = PAN: all.

study. In a recent study the two techniques, MOSFET and TLD, were found to be in good agreement.⁷

A film-based method has been described in the literature using GafChromic XR-QA2 film, a method for absorbed dose measurements where the film is placed between selected levels in a phantom. After exposure the film is scanned and the absorbed dose may be calculated according to the dose response function.¹⁰ A further described method used in a previous study for CBCT, excluding exposures on a phantom, is Monte Carlo simulations, where organ and effective doses are calculated using the ICRP voxel reference computational phantoms.¹¹

In the present study, the MOSFET technique was applied since it provides absorbed dose values immediately after exposure and enables continuous multiple readings in a row for the different collimation protocols with the phantom in an unaltered position. Furthermore, this technique eliminates measurement errors resulting from changes in placement of phantom and dosimeters, making the comparison between multiple exposures with different collimation protocols more reliable. Considering the number of dosimeters distributed in the phantom the effective doses measured for the smaller FOVs should be considered as indicative.

As presented in Table 2, extrathoracic airways, oral mucosa, salivary glands, bone marrow, and thyroid contributed most to the level of effective dose for all the panoramic collimation protocols in the present study. These findings are in agreement with an earlier study.¹² The organs contributing the most to the effective dose are also the organs affected most by the collimation in terms of reduced absorbed dose.

Although the dose from panoramic imaging is small compared with other medical radiographic examinations, the latest knowledge in the field state that all dose contributions counts. Our study showed that it was an

effective approach to reduce patient dose by applying collimation function in panoramic radiography. Possible indications for collimated panoramic examination are when a specific region of interest can be identified based on anamneses and clinical examination. As a consequence of a limited exposure area fewer incidental radiographic findings are expected. Incidental findings are relatively rare in panoramic radiography and therefore chosen FOV should only include the regions of interest in order to reduce the dose.¹³ However, by using full size panoramic radiographs potential important findings might be revealed that with limited FOV might have been missed. Examples of such findings are signs of osteomyelitis, cystic or tumorous lesions, carotid artery stenosis, and signs of osteoporosis.^{14–17}

The collimation function of panoramic radiographic units varies in exposure area depending on the manufacturer. Most of the manufacturers provide the collimation options of jaw, side, and individual quadrants. The possibility to choose between adult panoramic program and child panoramic program is common in most panoramic radiographic units on the market. The results in our study indicate that full size panoramic imaging might only be necessary in 20% of the examinations and that the FOV including teeth and supporting bone might be sufficient in 60% of the examinations reducing the dose by approximately 40% per panoramic image. Therefore implementing the collimation function in the clinical routines is recommended since it will enable a considerable dose reduction.

In recent studies, the effective dose from full size panoramic images using the 2007 ICRP tissue weights was 19–75 μSv ⁵ and 8.9–37.8 μSv ¹² in comparison with 17.6 μSv in the present study. The reason the relatively large spectrum in effective dose reported can be several, including a variation in panoramic devices, applied exposure parameters, and the choice of method of measuring the equivalent dose.

Our data are based on adult phantom and adult patients. The collimation function may be even more applicable in children since they are at a potentially higher risk than adults due to longer expected lifetime and higher radiosensitivity. The calculated risk for patients aged up to 10 years old are 3 times higher compared with 30 years old patients. The risk factor represents an average for both genders; however risks for females are slightly higher than those for males at all ages.¹⁸ Therefore dose optimization are highly desirable in children. A common indication for radiographic dental examination in young children is general manifestation of manifest caries in order to access numbers of and the extent of cavities as well as infection control. In combination with noncooperation with the intraoral radiographic examination a collimated panoramic image of the teeth and alveolar crests might be an alternative choice.

Svanaes *et al*¹⁹ suggested modification of the panoramic examinations on children by altering the height and width of the irradiated film area. Including

the use of a vertical extra collimator and an electronic timing device to reduce the exposed field to encompass only the developing dentition and supporting structures. They reported a reduction of the integral absorbed dose by about 60%.¹⁹ A similar study performed by Loght reported a reduced thyroid gland dose by 69%.²⁰

The most common reasons for prescribing a panoramic radiograph in this study was due to dental implant treatment followed by assessing dental status. For both indications the suggested protocol was PAN 5 which should cover the field of interest. Reasons for full size panoramic radiograph were temporomandibular joint disorders, trauma, and orthodontic treatment/orthognathic surgery. However, even among these patients potential for collimation might exist. Among the remaining reasons for referral *i.e.* prior to tooth removal, postsurgical problems/follow-ups, cysts, tumors, bone disease, numbness and infection, the adequate FOV is depended on the region of interest.

This study analyzed the referrals to a specialist clinic in dentomaxillofacial radiology that probably has a wider variety of diagnostic queries compared with a general dental clinic. The proportions of the different collimations most likely differ, since a general dental clinic probably have more questions regarding teeth and surrounding bone enabling smaller region of interest compared with a specialist clinic in dentomaxillofacial radiology.

Prior to removal of mandibular third molars the position of the wisdom tooth in the mandible decides whether PAN 4 or PAN 10 can be chosen. The latter provides a larger FOV displaying the anterior part of the mandibular ramus. PAN 10 compared with PAN 4 will also decrease the risk of not fully displaying the complete root morphology. Therefore PAN 10 was routinely chosen in the study. The difference in effective dose between PAN 10 and PAN 4 is 0.9 μSv . In the present study, 60.7% ($n = 153$) of the referrals have the interest restricted to teeth and supporting bone giving a dose reduction of 59.7% by applying the collimation in PAN 5. To support the clinical use of collimated panoramic radiography in the future, prospective studies are needed.

Not all the panoramic devices have the possibility of fine-defined collimation protocols. Furthermore, as a clinical routine there might not be feasible to handle as many as 10 different collimation protocols. Therefore, as an alternative the number of selectable collimation protocols can be reduced to those being most clinically applicable. In the present study, the three most clinically applicable collimation protocols on adult patients in a university environment were OPG 5, OPG 1, and OPG 10. Using only these three protocols gave a potential dose reduction of 31.5%. A minor improvement was seen if OPG 3 and OPG 9 was used as well, resulting in a potential dose reduction of 35.1%. Using more than five different collimation protocols showed negligible benefits for this patient group.

Conclusion

By limiting the exposure area, if the indication for radiographic examination allows, the effective dose can be decreased up to approximately 87% depending on the clinical questions. Restricting the collimation of panoramic images may be applied in 80% of referred adult patients at our university clinic. The most applicable collimation protocol was PAN 5 including teeth and supporting bone applicable in 61% of the referrals. The three most usable collimations were PAN 5 for examinations related to all teeth and supporting bone, PAN 1 when a full size image were indicated and OPG

10 restricted to unilateral mandibular molars. These three collimations are sufficient in 88% of the referrals, with 31.5% percent of dose reduction, and therefore the most important collimations in daily clinical routine. It may be of general interest to routinely limit the examination to the area of interest.

The study has ethical approval from the ethical committee in Stockholm, Karolinska Institutet with Dnr: 2013//1701-31/3 and amendment dated 2015-04-15.

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