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Radiological examinations of children: a study of method options

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SSM's perspective

Background

SSM performed a previous study of justification in the area of computed tomography in Sweden. The findings were based on a team of physicians determining retrospectively, on the basis of referrals, whether a sample of CT examinations performed in Sweden over the course of one day showed that the examinations were justified. The study resulted in a report published by the Swedish Radiation Safety Authority, SSM, entitled "National Survey on Justification of CT-examinations in Sweden", SSM Report 2009:03. These were the key findings:

- Approx. 20 per cent of the examinations performed were considered as not justified;
- The quality of the referral content was generally good;
- Justification varied depending on the part of the body examined;
- There were minor regional differences in Sweden;
- There were no differences between examinations on the part of males and females; and
- The level of justification was lower for children and adolescents.

Radiation protection rests on three basic principles: justification, optimisation and dose constraints. Justification implies the benefit of radiation exposure outweighing the risk of detriment. For each patient, one is to adapt (optimise) the examination to this patient and his or her illness. No dose limits are applied in connection with medical exposures as this could have a negative impact on the examination or treatment.

Assessing justification as per ICRP guidelines is performed at three levels. The first level involves determining whether or not to use radiation as part of medical care. The second level involves determining whether any type of examination could give an answer to a particular clinical question. Medical care programmes developed by medical care regions or professional organisations often serve as the basis of level two decisions. Level three involves determining the kind of examination or treatment that is optimal for the individual patient. The referring practitioner and the specialist performing the examination both determine whether an individual examination is justified. The referring practitioner has the task of determining whether an examination is needed. An adequate referral is to help the radiologist decide on an optimal choice of examination and give input for optimisation.

Aim

The purpose of this study was to verify whether the results from the first study were correct, that is, whether the level of justification is indeed relatively inferior on the part of children and adolescents in relation to adults. For the purpose of investigation, all referrals for computed tomography (CT), ultrasound (US) and magnetic resonance imaging (MRI) were collected from paediatric examinations performed over the course of two weeks at Swedish hospitals.

Outcome

This report largely confirms the findings from the previous study. The national survey also shows a considerable level of disagreement in Sweden in terms of when to perform a CT examination in paediatrics, since the reviewing physicians and performing radiology departments were only in agreement for 51 per cent of the examinations. This indicates suboptimal assessment of justification at level 2. It is crucial that medical care regions and scientific societies develop referral guidelines for diagnostic imaging.

Project information

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Reference: SSM 2011-1413
English translation: Anders Moxness, SSM

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This report concerns a study which has been conducted for the Swedish Radiation Safety Authority, SSM. The conclusions and viewpoints presented in the report are those of the author/authors and do not necessarily coincide with those of the SSM.

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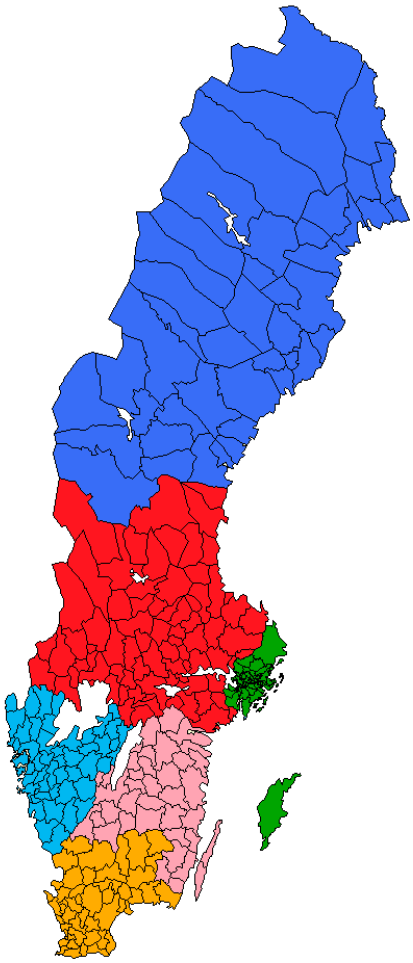

Medical care regions in Sweden, 2012

Region	CT	MRI	Million residents	Number of children	Percentage of children (%)
North	18	14	0.88	147,000	16.8
Uppsala-Örebro	39	29	1.97	341,000	17.4
Stockholm-Gotland	39	39	2.11	404,000	19.1
West	38	24	1.73	311,000	18.0
Southeast	22	18	1.00	176,000	17.6
South	34	25	1.73	310,000	17.9

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1. Executive summary

The Swedish Radiation Safety Authority, SSM, decided in 2011 to investigate the justification of the use of diagnostic computed tomography (CT) for children up to fifteen years of age. The reason is the fact that CT is the main contributor to ionising radiation to the population. During the last decade, the annual number of CT examinations increased by 200%, and during the last 16 years, by 320%.

In the present study, 3,149 CT, magnetic resonance imaging (MRI) and ultrasound (US) examinations in Sweden of children and adolescents aged 0-15 were performed over a 14 day period in 2011, encompassing all health care regions. Evaluation was performed by 18 experienced paediatric clinicians and radiologists. The observers were blinded for the referring practitioners' choice of method as well as for the performed examination method, but they had access to all other information given in the request forms (referrals). Each examination was judged by at least two observers, in a few cases by three or four observers.

Findings: Radiological *examinations* were judged as justified or probably justified for 96% of all examinations and as probably unjustified for 4% of the examinations. The information in the request forms was judged to be adequate or almost adequate, while 4% of the requests were considered as not fully adequate.

- The observers agreed on the choice of examination method, between the observers as well as with the requested and performed method, in 88% of requested US, in 68% of MRI and in 51% of CT examinations.
- The observers agreed among themselves on preferring another examination method than the one requested and other than the performed method in 2% of US, in 5% of MRI and in 14% of CT examinations.
- The observers disagreed among themselves and at least one observer agreed on the requested choice of method in 9% of US, in 25% of MRI and in 32% of CT examinations.

Regional variation in the use of CT was demonstrated.

Discussion: There is a high level of national consensus among paediatric clinicians and radiologists concerning the use of US as the adequate method of choice in actual clinical practice. The lower level of agreement regarding CT as the method of choice suggests that clinical guidelines either do not exist, or are suboptimal, or have not yet reached common acceptance in the paediatric healthcare community. During the past decade, parallel to the development of much more optimal techniques leading to steadily increased use of CT, access to

MRI has slowly but steadily improved at almost all Swedish county hospitals. Still, there may be clinically unacceptable, long waiting times for MRI (and especially for MRI of children in general anaesthesia), leading to the next best choice of CT for the examination. These circumstances may be important and one reason behind the level of disagreement becoming evident in the present study. The paediatric physician in routine practice may not only be able to choose the most appropriate examination with the lowest radiation dose to the child, but must for example consider choosing between drop-in for CT and very long waiting times for MRI.

In the present study, regional differences were assessed. CT requested by university and county hospitals was considered to be more justified than CT requested by physicians in primary care, though requests from primary care were infrequent.

In a similar investigation in 2004 on the use of MRI, conducted by the same team of experts, the observers considered about one-third of the studied MRI examinations as being unjustified and 20% to 25% of the requests were considered to be inadequate.

It is of material importance to increase efforts to define and establish optimal referral guidelines for paediatric imaging in general and for the use of CT for children in particular.

2. Introduction

One of the basic principles of radiation protection in radiological diagnostics is for the benefit for the patient to outweigh the estimated detriment/risk from an examination involving ionising radiation.

There is a consensus concerning replacement of examinations involving ionising radiation by examinations that do not involve radiation, provided that the replacement examination has the sufficient/necessary diagnostic accuracy for the given clinical question. This consensus is based on the general precautionary principle and avoidance of potential risks; for example, future development of malignancy or other illnesses. As computed tomography (CT) currently contributes more than half of the total radiation dose received by the Swedish population, a national survey of the choice between CT, magnetic resonance imaging (MRI) and ultrasound (US) examinations as alternative methods is of particular importance for paediatrics.

The Swedish Radiation Safety Authority (SSM) appointed a project team for this assignment, referred to as the team of experts in this report. This review team had carried out three similar studies on use of magnetic resonance imaging (MRI) by Stockholm County Council in 2001 and 2004, in addition to a national survey on use of computed tomography in 2006. All the studies were retrospective and observational. The total number of radiological imaging procedures in Sweden is constant in relation to the population, with a significant shift towards more radiation-based CT (1, 2, 3).

Alternative methods to paediatric CT show satisfactory distribution, mainly US. The level of access to CT is generally high and examination times are short, at the same time as access to MRI is limited. Children under six years of age may in exceptional cases undergo MRI examinations without anaesthesia, which limits their use. During drop-in time, access to anaesthesia is limited. The degree of justification of paediatric examinations has not been surveyed previously.

3. Background

Modern CT equipment offers very good imaging of the body and is in many cases a necessary diagnostic tool for confirming or ruling out serious illness, or for planning of treatment; CT is frequently used for follow-ups. CT is faster and gives better image quality in a free choice of directions and has good availability around the clock, thus contributing to gradually increased use.

In 2006, the Swedish Radiation Safety Authority (SSM) initiated a national study on use of CT procedures. The study encompassed 2,345 CT examinations performed over the course of 24 hours in the month of March 2006 (Report 2009:3) (1). Report 2009:3 covered a small number of children and adolescents ages 0-15 (N = 111/2,345).

CT represents more than half of the collective dose from diagnostic radiology; use of CT is increasing by 5–10% annually. In Stockholm County, the total number of CT examinations rose from 65,000 in 1996 to approx. 210,000 in 2011, thus more than tripling over a 16-year period. For the year 2011, it was estimated that nearly one million CT examinations in total were carried out in Sweden. In relation to the population, an estimated one out of ten adults are examined annually using CT. The number of paediatric CT examinations has not been studied previously. New areas of application have arisen replacing conventional radiology, for instance for trauma examinations, vessels, the urinary tract and 3-D reconstructions.

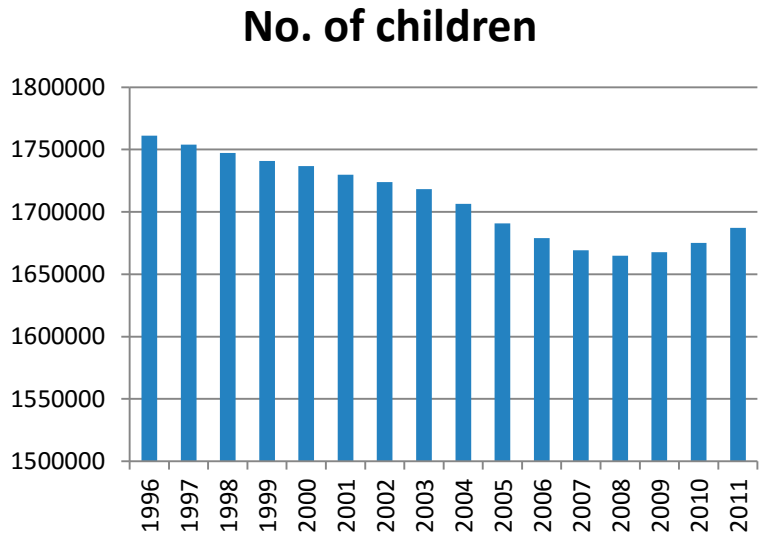

Figure 1 Number of children in Sweden between 1996 and 2011 (source: Statistics Sweden)
Development in the number of children throughout Sweden under the age of 16. The lowest number of children was in 2008. This was followed by an increase. The total decline amounted to 4.2% during the period.

Risk of developing cancer following CT examinations

The general perception is that there is no absolute lowest level for radiological medical exposure in terms of cancer risk. This is why procedures follow the principle of using the lowest possible radiation dose in connection with radiological examinations. The absolute risk of developing a cancer illness due to diagnostic medical exposure is small and generally the benefits outweigh the potential risk of developing cancer.

Epidemiological studies show that children have greater sensitivity to ionising radiation than adults. Given that they have a longer life expectancy than adults, children and adolescents run a higher risk of radiation injury. There is a risk that children will receive a higher radiation dose than necessary for giving sufficient diagnostic information. Children and adolescents altogether run a multiple risk of developing radiation-related cancer illnesses compared with adults who have undergone the same kind of radiological imaging procedure. Previous estimates of the radiation hazard for children showed that the lifelong risk of developing cancer rose substantially for children, indicating the need to limit radiation doses (5, 6). The first study published that specifically assessed the risk of developing cancer following CT examinations in childhood was released in June 2012 (7). Scrutiny revealed that for 176,587 patients, the risk was cumulative in pace with higher radiation dose. A dose of 50-60 mGy to the skull region was estimated to triple the risk of developing a brain tumour. The same radiation dose to bone marrow, for example when examining bone marrow areas such as in the thorax/chest, spine and abdomen, triples the risk of developing leukaemia. A corresponding group of individuals who did not undergo a radiological examination was estimated to receive a cumulative dose of less than 5 mGy.

4. Purpose of this study

The assignment was to perform an analysis of justification, method options and referral quality in the area of paediatric CT examinations for children and adolescents between the ages of 0 and 15.

It is crucial to comply with guidelines and to have a high level of clinical quality when using diagnostic imaging involving medical exposures of children and adolescents. This particularly applies to CT examinations. US and MRI are methods of diagnostic imaging that do not expose patients to ionising radiation. It is assessed as important to perform analyses on the extent to which CT, US and MRI performed on children were justified, and on whether the selected method is correct.

SSM's regulations require licensees to ensure that all medical exposure is justified and optimised. SSM has introduced the concept of "diagnostic reference levels" for some examinations, a dose level which should not be exceeded. This has led to successful optimisation work in health and medical services.

Justification is defined by SSM regulation 2008:35 (8). Alternatively, justification can be defined in accordance with guidelines for requesting imaging diagnostics (Referral guidelines for imaging: Radiation Protection 118, EU 2000, 2008) (9, 10).

The objectives of the study were to:

a) look into areas such as equipment standard and the existence of protocols at Swedish medical diagnostic departments that perform paediatric examinations;
b) present areas such as:
    i. statistics on the number of paediatric examinations using the methods CT, MRI and US, categorised by age category, gender, medical care region, county, level of medical care, referrers' specialty, organ areas examined and public/private medical services,
    ii. the reviewers' assessment of referrals in terms of the referrals' quality and the examinations' justification, and
    iii. the reviewers' choice of preferred method independently of the referring practitioner's and examining radiologist's choice, in addition to the level of agreement between reviewers and agreement between reviewer and referring practitioner; and
c) analyse the outcomes, mainly review work, and based on analysis and interpretation, suggest areas of focus for improvement

work on guidelines and care programmes on national and regional levels.

Approaches

In order to strive to achieve the objectives, the decision was made to conduct a simple *survey* in addition to a *review study*.

The *questionnaires*, which were completed by heads at all diagnostic imaging departments in Sweden, were intended to shed light on existing and available equipment and whether the dose reduction software for CT was applied on a routine basis. Responses were sought on anaesthesia options and protocols (care programmes) for paediatric radiological examinations using CT, MRI and US.

The *review study* implied examining referrals and responses over a 14 day period of producing CT, MRI and US examinations at all radiology departments in Sweden for the purpose of forming an opinion on the reviewers' assessments of justification, referral quality and the selected method. The review was based on the reviewer personally assessing which method of CT, MRI or US that was most appropriate on the basis of referral details.

Confidentiality and patient participation

Copies of referrals for assessment by the reviewers were de-identified. Only the first name and four digits of the personal identity number were not de-identified. All referral details that could potentially be traced to a specific patient referral or subsequently performed examination were also removed. Opinions on examinations were compiled, but the reviewers did not have access to a specific opinion. Patients and their guardians did not take part in this study.

Questionnaire to heads of departments

SSM sent a questionnaire to heads of diagnostic medical imaging departments in Sweden. The questionnaire sought responses to the following questions:

- Was CT, MRI and US equipment available at the clinic?
- Was there dose reduction software for CT, and if so, which software was it?
- Was there access to anaesthesia for general anaesthesia, in particular for MRI scans of children?
- Were there protocols (care programmes) for diagnostic imaging examinations of children (CT, MRI and US, but also other methods)?

5. Review study

Population

The material consisted of referrals and responses (results of examinations) for all the CT, MRI and US examinations of children aged 0-15 performed during the period as of 0:00 hours, Wednesday 23 March 2011 up to and including 24:00 hours, Tuesday 5 April 2011 at all departments located in Sweden. In the event any modality was non-operational for a maximum of six hours during a particular 24-hour period of the selected timespan, that day was replaced by compilation during an alternative day immediately before or after the period studied.

Design: Collecting material comprising referrals and responses

The study is retrospective and observational.

The material collected in Sweden comprised all complete referrals with results of examinations for children under 15 years of age (excluding 15 years and older, with the exception of a few individual adolescents aged 15 and up who are included and are still being cared for in paediatrics), and material on performed or not completed CT, MRI and US examinations during the period as of 00:00 hours, 23 March 2011 up to and including 24:00 hours, 5 April 2011, compiled electronically or as paper copies.

In the event any modality was non-operational for a maximum of six hours during a particular 24-hour period, that day was replaced by compilation during a day before or after the studied period. Referrals were to contain all patient details and complete clinical details, including information about the clinic, hospital (or outpatient care) and county council where the referring practitioner worked.

Following collection, surnames and personal identity numbers were de-identified by SSM, the Swedish Radiation Safety Authority.

Descriptive data

Referrals and responses for all examinations were assigned a unique number. All the below referral details were entered into the study database:

- Patient data: birth year, month, day, gender

- The referring practitioner: county council, specialty, care level, clinic/department, public or private
- The diagnostic imaging department performing the examination: county council, care level, clinic/department, public or private
- The examination *requested* by the referring practitioner: method option, part of the body
- The performed examination: method, part of the body
- Referral date and examination date
- If the serum creatinine value was provided
- If information was provided on the patient not being pregnant
- If the examination was performed with or without using I.V. contrast injection
- If the referral was handwritten
- Any referral comments

Reviewing physicians

The team of experts turned to radiology representatives for selection of reviewing physicians with expertise in the practice. The representatives suggested suitable reviewers. All the reviewers have specialist competence and extensive professional experience.

The reviewers who represent clinics were to have as their main occupation clinical work involving paediatric patients in medical care, covering the modalities CT, MRI and US, have extensive and broad clinical experience and, as a minimum, be partly in charge of an operation involving a high proportion of paediatric patients referred for diagnostic CT, MRI and US.

Reviewers who are radiologists were to be clinically oriented, have extensive and broad imaging and functional diagnostics experience, primarily in paediatric and adolescent radiology, and be well known collaborative partners for clinics/referring practitioners.

All reviewers were to be acknowledged as being of sound judgement and known for their integrity. The 18 reviewers engaged represented university hospitals, county hospitals, district hospitals, both public and private. The reviewers are specialists in paediatric and adolescent radiology, in paediatric and adolescent medicine, and in clinical subspecialties of orthopaedics, surgery, neurology and oncology. The reviewers held posts at departments in Lund, Halmstad, Linköping, Stockholm (Solna), Stockholm (Danderyd), Stockholm (MRAB), Uppsala, Falun and Hudiksvall.

Data entry: descriptive information

The team of experts entered all descriptive information (see above) into a specially designed database. All 18 reviewers were provided with a unique database copy. The reviewers were assigned a workset comprising 200 to 550 referrals.

The following collected details were registered centrally by the team of experts:

Patient:	Birth year, month, day, gender Referral date, examination date
Referring practitioner:	County council, department, specialty, owner, care level, department Level of medical care (university hospital, county hospital, district hospital), outpatient care Ownership (public, private practitioners under own management, private care enterprise) *Requested* by the referring practitioner: method, part of the body
Radiologist:	Region, county council, department, owner, care level Level of medical care (university hospital, county hospital, district hospital), outpatient care Ownership (public, private practitioners under own management, private care enterprise) Method, part of the body. Referral date, examination date. Any deviating creatinine value
Examination:	Requested examination – method and part of the body/organ Performed examination – method and part of the body/organ Information about denied pregnancy Was I.V. contrast medium used? Handwritten referral Any referral comments

Review of referrals

The copies of referrals supplied to the reviewers had not only the examination method de-identified, but also any other information that could potentially be used to deduce the method of examination performed.

Consequently, the reviewers assessed referrals where the patients' birth year, month and day, in addition to their first name, were accessible. Moreover, the reviewers could access all referral details in other respects. The reviewers could not access examination results.

Each reviewer received own copies of selected referrals for the purpose of entering their assessments and preferred choice of method in their own database. All the assessments were merged as part of a large shared database. Each referral was examined by a minimum of two reviewers, radiologists or clinics. Some referrals were examined three or four times.

Referral procedure and referral quality

The standard for referrals can be defined as criteria developed, established and accepted by the profession for referral content required for an investigation or for consultation (10).

Radiation protection regulations impose restrictions on examinations involving ionising radiation. A radiologist has not only an obligation, but also the right, to consider the justification and choice of examination method. This procedure includes changing the examination suggested by the referral in order to ensure protection of patients. Local procedures for complete referral management must be issued (11, 12, 13).

Reviewer assessments

The reviewers were asked to adopt a standpoint on all the referral information available to them (see above), using this information to assess and grade the referral quality and justification, in addition to choosing the preferred examination method and part of the body to investigate.

The reviewers were instructed to grade referral quality and justification in accordance with definitions. In other respects, there was no requirement on specific knowledge of applicable international, national or regional guidelines or care programmes. Assessments were mainly to be based on proven experience, but also on national guidelines or

generally accepted principles to the extent that a reviewer was aware of them.

When assessing referral quality and justification, the reviewers were instructed to learn about definitions for grading these aspects.

Referral quality

Referral quality is measured by the degree to which referral information is sufficient and adequate. The definition of "degree" is based on the possibility to, from the referral details, assess an examination's *efficacy (= required technical and diagnostic accuracy)* and its *justification (see definitions of "justification")*. Degrees of adequate referral information may be defined in accordance with the following:

- *Adequate referral information*: efficacy and justification can be assessed.
- *Relatively adequate referral information*: efficacy can be assessed, it is not self-evident that justification can be assessed.
- *Relatively inadequate referral information*: it is not self-evident that efficacy can be assessed, justification is difficult to assess.
- *Inadequate referral information*: the referral lacks details to a degree preventing the question's relevance from being assessed. Efficacy and justification cannot be assessed.

Justification

There are two definitions for justification of diagnostic imaging examinations. One definition is provided by the EU's "Referral guidelines for imaging" (9). Another definition is laid down by SSM's regulation SSMFS 2008:35 (8). See the discussion below contained in the present report, where these definitions are cited and their implications are discussed.

The degree of justification has been defined by this study as a response to this question: Can the outcome of this examination – positive or negative – be expected to be of significance for further investigations or therapy, or, alternatively, give a sufficiently accurate diagnosis:

Definitely	- Justified examination
With a high level of probability	- Justified examination probable
With a relatively low	- Justified examination unlikely

level of probability	
Not at all	- Unjustified examination
Cannot be assessed	- The referral details are insufficient for assessing the possible outcome of the examination

Since the reviewers were neither aware of the examination methods requested nor performed, the emphasis of the review definition was automatically placed on the general definition and not on SSM's definition. The reviewers were instructed to adopt a standpoint as to whether any diagnostic imaging examination was justified judging from the referral information; the next step for them was to choose their preferred examination method.

Method options

The reviewers were asked to, on the basis of the available referral information, choose the most justified examination method without knowing what the referring practitioner requested or the method used for the examination. The choice did not force the reviewers to decide between CT, MRI or US. Instead, they could select other diagnostic imaging or interventional methods, such as conventional X-ray, scintigraphy or conventional angiography. The choice of method was to be made if the reviewer assessed that the examination was justified, its justification highly probable, or unlikely. The reviewers were also asked to choose a part of the body to investigate. If a reviewer was of the opinion that two examinations with different methods were justified, an additional examination and respective part of the body could be indicated.

6. Outcomes

Material and statistics

The study included 3,149 examinations performed over two weeks in Sweden, between 23 March and 5 April 2011, involving CT, MRI and US of children aged 0–15 (Table 1).

1,507 girls and 1,641 boys were examined, with one patient of unknown gender on the basis of referral details (Table 1, Figure 2).

Table 1. Number of examinations, gender perspective and number of reviews.
Number of examinations CT, MRI and US performed in paediatrics, children aged 0-15, with a small number of patients over 15 years of age still being monitored by paediatric services. The period studied comprised 14 days between 23 March and 5 April 2011.

Demographic data		
No. of examinations		3149
Sex	Girls	1507 (48%)
	Boys	1641 (52%)
	unknown	1
No. of reviews		6656
Referral review	2 times	2802
	3 times	336
	4 times	11

The number of examinations performed was 3,149. Each examination was reviewed by a minimum of two independent reviewers; a few examinations were reviewed by three or four reviewers. The total number of reviewed examinations was 6,656. The period of the study was selected based on anticipated full production in health and medical services for acute and elective care. Actual yearly production should be somewhat lower than what can be estimated by extrapolating from production during the period studied.

For the purpose of drawing conclusions, the number of examinations is deemed sufficient during the period of time as far as concerns methods, organ areas and the respective medical care regions.

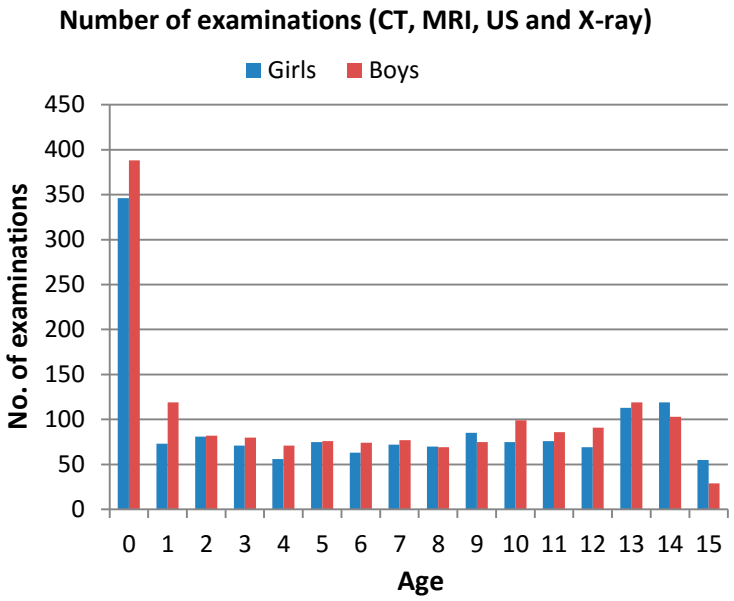

Figure 2. Number of examinations performed during the selected period, CT, MRI and US, by gender and age category.
The number of examinations for babies and infants predominate, followed by a gradual decrease and subsequently slow increase. The category children aged 0-1, from the neonatal period and up to the 12th month, represents serious illnesses.

Of the number of examinations performed (3,149), 653 were CT, 663 MRI, 1,832 US and 1 X-ray. The distribution was 1/1/2.7 (Table 1, Figures 3, 4, 5).

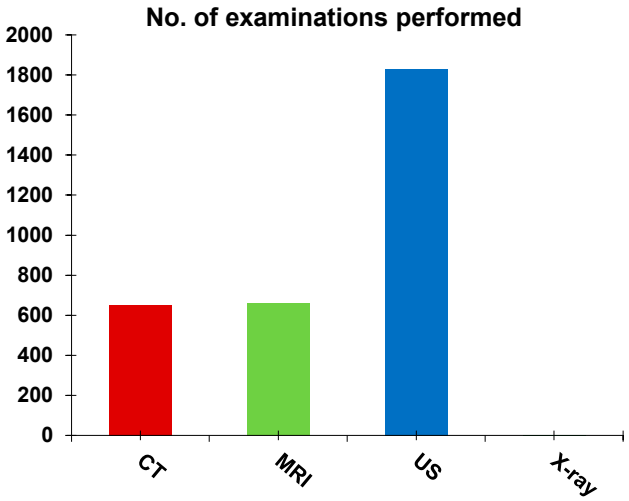

Figure 3. Number of examinations performed during the selected period, CT, MRI, US and X-ray.
US is the predominant modality. MRI and CT are relatively evenly distributed among the number of examinations. Ratio CT/MRI/US: 1/1/2.7.

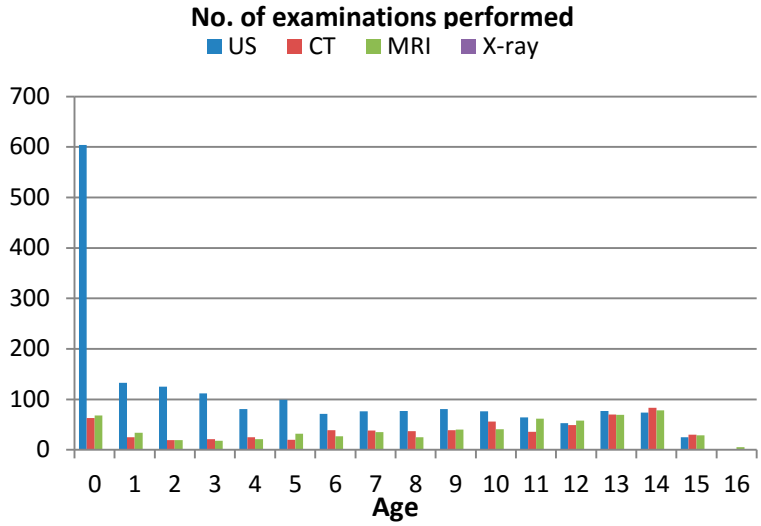

Figure 4. Number of examinations performed during the selected period, CT, MRI, US and X-ray, per age category from 0-15 years.
US predominates considerably for children up to two years, mainly for ages 0-1 during the neonatal period. The number of CT and MRI examinations slowly increases with children's age.

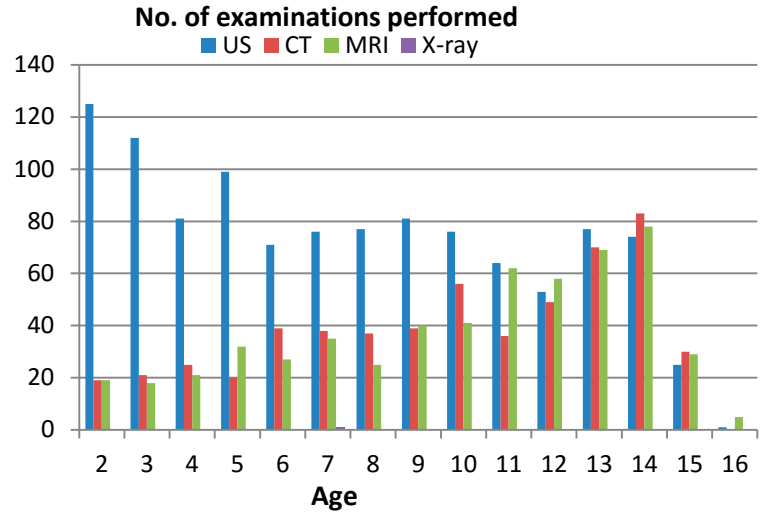

Figure 5. Number of examinations performed using the method requested by the referring practitioner, CT, MRI, US and X-ray, per age category from 2 to 15 years.
The number of US drops after infants' first 12 months. CT and MRI are used to a limited extent for younger ages, with their use increasing gradually with the children's age.

CT and MRI increase somewhat by number of examinations with rising age, whereas US examinations predominate during the neonatal period (40% of all US were of children aged 0-2), dropping to a stable

frequency per age category from 2 years of age and older (Figures 2, 4, 5, 6).

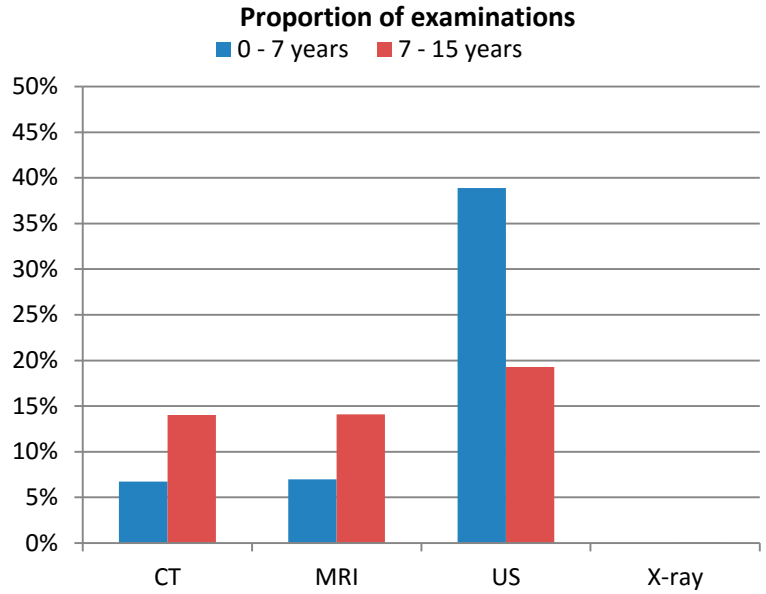

Figure 6. Proportion of CT, MRI and US for children aged 0–7 and 7–15. US is the predominant modality, particularly for ages 0–7.

The distribution of examinations (N=3,149) in six medical care regions is shown per million children. The lowest number of examinations was performed in the Uppsala-Örebro region (1,611 examinations per million children). The highest number was performed in the Stockholm-Gotland region (2,192 per million children) (Figure 7).

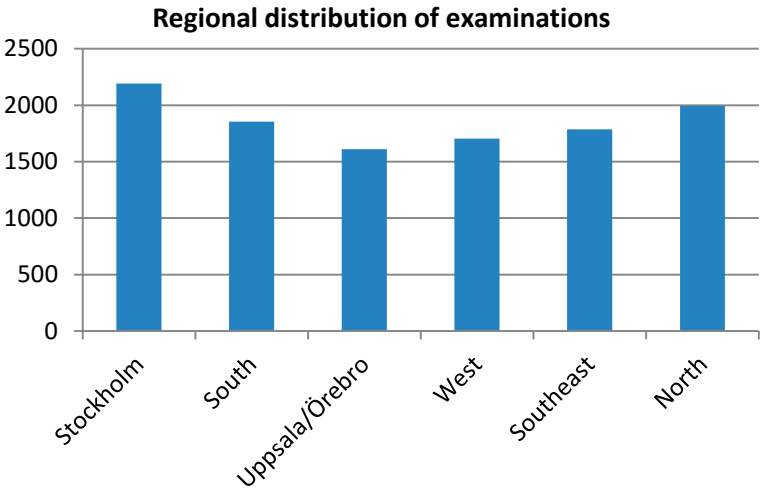

Figure 7. Number of CT, MRI and US examinations per million children during the selected period per medical care region (number of children aged 0-15 according to Statistics Sweden).

As regards the Stockholm-Gotland region, a higher number of US contributed to the total number of examinations (+18%) exceeding the national average. A higher number of US for the Stockholm-Gotland region may be due to concentration of specialist care with a high level of access to US at a small number of departments, compared with Sweden on a national level.

The number of CT, MRI and US examinations per million children varies between county councils, counting from the mean value, from +56% (Västerbotten County Council) to –35% (Region Halland) (Figure 8).

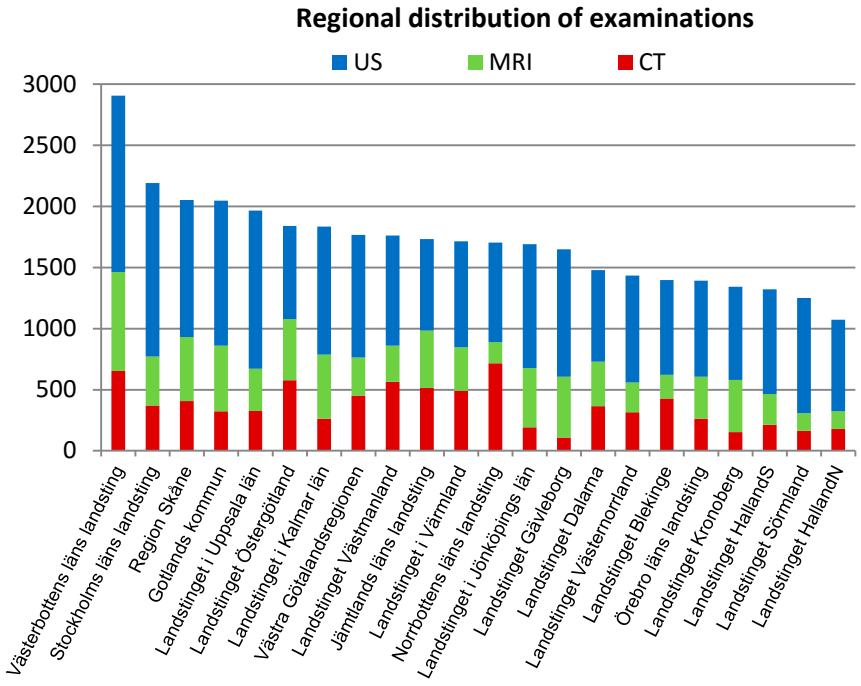

Figure 8. Number of CT, MRI and US examinations per million children aged 0-15 by county council (number of children as per 1 January 2011 according to Statistics Sweden).

There is a discernible variation in the use of CT, MRI and US between county councils. The highest number of examinations is represented by Västerbotten County Council. The lowest number of examinations is represented by the Halland region, disparity factor of 2.4 per million children. A large variation is also discernible in terms of method selection. The highest number of CT examinations is shown by Norrbotten County Council; the lowest by Gävleborg County Council, factor 6.6.

The number of referrals for CT examinations per million children was lowest in the Uppsala-Örebro region, at 310, and highest in the North region, at 529 (Figure 9).

The number of referrals for MRI examinations per million children was lowest in the West region, at 296, and highest in the Southeast region, at 499 (Figure 9).

The number of referrals for US examinations per million children was lowest in the Southeast region, at 902, and highest in the Stockholm-Gotland region, at 1,405 (Figure 9).

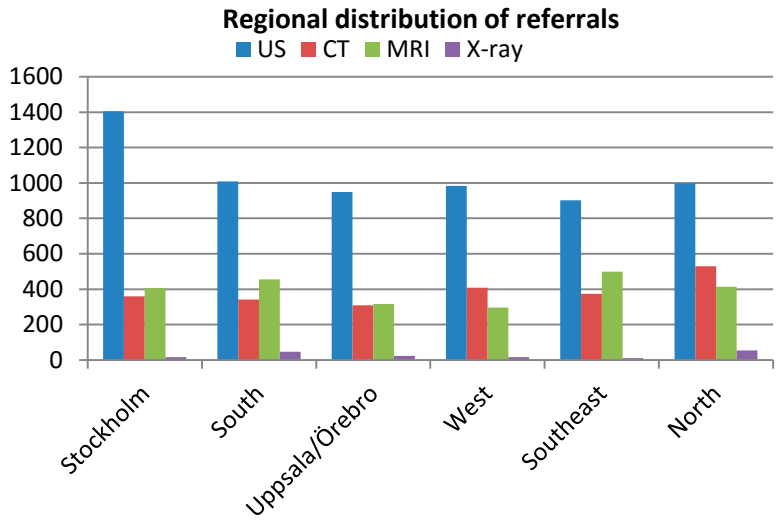

Figure 9. Number of referrals for CT, MRI, US and X-ray per million children and by region.
US predominated in the Stockholm-Gotland region. The Southeast region had the highest proportion of MRI, and CT was predominant in the North region.

The frequency of performed examinations in paediatrics is dominated by university hospitals at 49%, followed by county hospitals at 30%, district hospitals at 16% and outpatient care at 5%. The distribution of examinations at care level is shown by Table 2.

Referrals from outpatient care (13%) were more common than examinations at departments in outpatient care (5%) (Table 2).

Table 2. Comparison of the number and percentage of examinations at different care levels, requested by a clinic and performed at the respective diagnostic imaging department at a university hospital, county hospital or district hospital, and requested by non-hospital affiliated outpatient care.
Referring practitioners may work at a care level that is different from the care level of radiology departments. Outpatient care refers a relatively high percentage of patients to a higher care level; this is also a desirable situation. A significant concentration of examinations at diagnostic imaging departments at higher levels of medical care, 49%, were performed at university hospitals, with 30% performed at county hospitals.

	Referrer		Examiner	
	No.		No.	
University hospitals	1494	47%	1556	49%
County hospitals	845	27%	938	30%
District hospitals	397	13%	508	16%
Outpatient care	409	13%	147	5%
Other	4	0%		

Table 3. Number and percentage of examinations requested and performed within the public care sector, a department in a private care company or by a physician with an own practice.
The public care sector predominates as far as concerns both referring departments and radiology departments.

Care provider	Referrer		Examiner	
Public	2999	96%	3007	96%
Private company	103	3%	101	3%
Private doctor	45	1%	41	1%
Other	2			

It is common for examinations to be requested and performed at university hospitals (Table 2; Figure 10).

The percentage of examinations requested by non-hospital affiliated outpatient care (family doctors, outpatient care specialists) was highest in Stockholm-Gotland (19%) and lowest in the North region (7%) (Figure 10). The percentage of examinations requested by university hospitals was highest in the Stockholm-Gotland region. Requests from county hospitals predominated in the Uppsala-Örebro region.

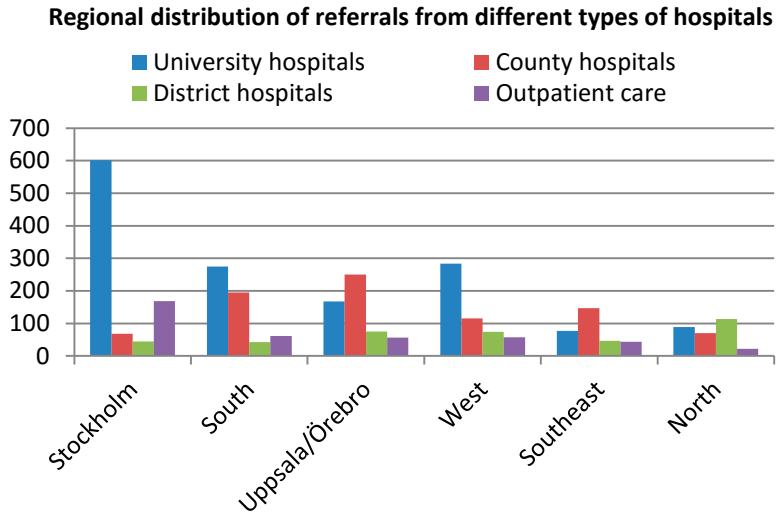

Figure 10. Number of CT, MRI and US examinations requested by clinics at university hospitals, county hospitals and district hospitals, and requested by non-hospital affiliated outpatient care, grouped by medical care region.
The structure of health and medical services varies between regions. The Stockholm-Gotland region has a concentrated structure, with the largest number of residents and paediatric care clustered at Astrid Lindgren Children's Hospital. An equivalent structure is also discernible in the West region. The other regions offer more medical services at county hospitals. At the same time, however, the Stockholm-Gotland region has a higher percentage of referring practitioners in outpatient care than compared with the other regions.

The largest number of referrals and performed examinations comprised cases involving the brain/skull, abdomen/pelvis and kidneys/urinary tract (Tables 4, 5, 6).

Table 4. Requests from different care levels grouped by most common organ areas.
The predominant organ areas are brain/skull, abdomen/pelvis and kidneys/urinary tract. 45 requested X-ray examinations were changed to US, CT and MRI. One X-ray examination was performed nevertheless.

	University hospital	County hospital	District hospital	Outpatient care	Total
Brain/skull	331	213	98	81	723
Abdomen/pelvis	394	180	72	74	720
Kidneys/urinary tract	208	156	60	49	473
Joints/soft tissue	137	68	43	98	346
Pelvis/hips	112	76	40	33	261
Head/neck	103	51	30	31	215
Testicles/scrotum	71	28	20	13	132
Spine	62	29	15	16	122
Thorax	36	17	6	7	66
Miscellaneous	28	13	5	6	52
Parts of skeleton	6	6	5	1	18
Trauma CT	6	8	3	0	17

Table 5. Performed examinations from different care levels, grouped by most common organ areas.
The predominant organ areas were brain/skull, abdomen/pelvis and kidneys/urinary tract, with the examinations mainly performed at university hospitals or county hospitals. Only a small number of examinations were performed using a method other than the one requested by the referring practitioner; compare with Figure 15.

	University hospital	County hospital	District hospital	Outpatient care	Total
Brain/skull	355	213	103	15	686
Abdomen/pelvis	408	182	96	28	714
Kidneys/urinary tract	226	177	68	10	481
Joints/soft tissue	135	83	72	56	346
Pelvis/hips	116	81	50	15	262
Head/neck	113	56	42	7	218
Testicles/scrotum	66	33	26	6	131
Spine	61	29	23	8	121
Thorax	36	18	10	2	66
Miscellaneous	28	11	10	0	49
Parts of skeleton	6	10	5	0	21
Trauma CT	6	8	3	0	17

Table 6. Number and percentage of CT, MRI and US examinations for the most common organ areas. Brain/skull is the predominant organ area for both CT, at 41.7%, and MRI, at 47.2%. The organ area abdomen/pelvis, at 34.0%, is predominant as far as concerns US.

CT	No.	
Brain/skull	272	41.7%
Head/neck	120	18.4%
Abdomen/pelvis	58	8.9%
Spine	50	7.7%
Joints/soft tissue	49	7.5%
Thorax	40	6.1%
Miscellaneous	18	2.8%
Trauma CT	17	2.6%
Parts of skeleton	14	2.1%
Pelvis/hips	12	1.8%
Kidneys/urinary tract	3	0.5%

MRI	No.	
Brain/skull	313	47.2%
Joints/soft tissue	169	25.5%
Spine	71	10.7%
Head/neck	35	5.3%
Abdomen/pelvis	33	5.0%
Pelvis/hips	18	2.7%
Thorax	16	2.4%
Parts of skeleton	7	1.1%
Kidneys/urinary tract	1	0.2%

US	No.	
Abdomen/pelvis	623	34.0%
Kidneys/urinary tract	477	26.0%
Pelvis/hips	232	12.7%
Brain/skull	138	7.5%
Testicles/scrotum	131	7.2%
Joints/soft tissue	127	6.9%
Head/neck	63	3.4%
Miscellaneous	31	1.7%
Thorax	10	0.5%

The most common referrer's specialty was paediatric and adolescent medicine, followed by acute medical care and orthopaedics (Tables 7, 8).

Table 7. Number and percentage of examinations requested by respective specialty.

Paediatric and adolescent medicine was the predominant specialty. Several specialties belong to acute medical care, though they are not specified in the requests. Consequently, only limited conclusions can be drawn in terms of specialty.

Referring specialties	No. of exams	
Paediatrics	1037	32.9%
Emergency care	614	19.5%
Orthopaedics	281	8.9%
General practice	226	7.2%
Paediatric surgery	179	5.7%
Neonatology	174	5.5%
Child neurology with habilitation	112	3.6%
Children oncology	88	2.8%
Surgery	86	2.7%
Otorhinolaryngology	62	2.0%
Urology	52	1.7%
Other specialties (N = 22)	238	7.6%

Table 8. The referring practitioner's requested method options of CT, MRI, US and X-ray, grouped by most common specialty (most referrals). Several specialties are accounted for that belong to acute medical care.

The specialty paediatric and adolescent medicine represents the majority of requests. The availability of MRI for acute medical care is low and more difficult to deal with, above all for children < 5 years.

Referring specialties	US	CT	MRI	X-ray	Total
Paediatrics	653	134	237	12	1036
Emergency care	397	177	31	9	614
Orthopaedics	111	58	110	2	281
General practice	113	37	59	15	224
Paediatric surgery	129	33	17	0	179
Neonatology	151	3	20	0	174
Child neurology with habilitation	29	35	48	0	112
Paediatric oncology	38	14	35	1	88
Surgery	57	20	5	4	86
Otorhinolaryngology	10	38	12	1	61
Other specialties	128	79	80	1	288

In 38 cases, examinations were performed using a different method with a higher radiation dose than the method requested by the referring practitioner. In 23 cases, examinations were performed using a different method with a lower radiation dose than the method requested by the referring practitioner (Table 9).

Table 9. Performed method other than the method requested, involving a higher, lower or the same radiation dose. The left-hand column shows the referrers' specialty.
The overall conclusion is that a changed method might imply either a higher or reduced radiation dose. The proportion of examinations that were changed is shown as a percentage.

	Examinations - other than requested	Examinations - with increased dose	Examinations - with lower dose	Examinations performed	Percentage change to higher dose
Paediatrics	16	9	7	888	1%
Emergency care	12	7	5	602	1%
Orthopaedics	2	1	1	279	0%
General practice	18	11	7	206	5%
Paediatric surgery	1	1	0	178	1%
Paediatric oncology	1	1	0	87	1%
Surgery	6	4	2	80	5%
Otorhinolaryngology	2	1	1	60	2%
Urology	1	1	0	51	2%
Paediatric cardiology	1	1	0	16	6%
Neurosurgery	1	1	0	16	6%

Marginal differences were found between requested and performed examinations on the part of all the modalities of CT, MRI and US for all organ areas (Tables 10, 11, 12).

Table 10. The most common organ areas for CT. A comparison between requested and performed examinations.
There were marginal differences between requested and performed CT examinations for all organ areas. The highest number was represented by brain/skull.

Note that the total number of reviews of referring practitioners' requests for CT, MRI and US examinations was 6,642. Seven examinations, corresponding to 14 reviews, were cases of the referring practitioner having chosen a different examination that is not presented.

CT	Referrals		Examinations	
Brain/skull	277	44.1%	272	41.7%
Head/neck	111	17.7%	120	18.4%
Abdomen/pelvis	54	8.6%	58	8.9%
Joints/soft tissue	44	7.0%	50	7.7%
Spine	42	6.7%	49	7.5%
Thorax	41	6.5%	40	6.1%
Miscellaneous	17	2.7%	18	2.8%
Trauma CT	17	2.7%	17	2.6%
Parts of skeleton	12	1.9%	14	2.1%
Pelvis/hips	11	1.8%	12	1.8%
Kidneys/urinary tract	2	0.3%	3	0.5%

Table 11. The most common organ areas for MRI. A comparison between requested and performed examinations.
There were marginal differences between requested and performed MRI examinations for all organ areas. The highest number was represented by brain/skull.

MRI	Referrals		Examinations	
Brain/skull	305	46.6%	313	47.2%
Joints/soft tissue	168	25.7%	169	25.5%
Spine	71	10.9%	71	10.7%
Abdomen/pelvis	35	5.4%	35	5.3%
Head/neck	34	5.2%	33	5.0%
Pelvis/hips	18	2.8%	18	2.7%
Thorax	16	2.4%	16	2.4%
Parts of skeleton	6	0.9%	7	1.1%
Kidneys/urinary tract	1	0.2%	1	0.2%

Table 12. The most common organ areas for US. A comparison between requested and performed examinations.
There were marginal differences between requested and performed US examinations for all organ areas. The highest number was represented by abdomen/pelvis.

US	Referrals		Examinations	
Abdomen/pelvis	624	34.4%	623	34.0%
Kidneys/urinary tract	467	25.7%	477	26.0%
Pelvis/hips	229	12.6%	232	12.7%
Brain/skull	136	7.5%	138	7.5%
Testicles/scrotum	132	7.3%	131	7.2%
Joints/soft tissue	124	6.8%	127	6.9%
Head/neck	64	3.5%	63	3.4%
Miscellaneous	31	1.7%	31	1.7%
Thorax	9	0.5%	10	0.5%

Brain/skull was the most common organ area examined using CT and MRI (Tables 6, 10, 11), and for US, abdomen/pelvis (Tables 6, 12).

The median waiting time for examinations was four days. Occasionally, extended waiting times are attributed to planned checks (Table 13).

Table 13. Waiting times from referral date to examination date.
Comment
The median value is 4 days; the maximum value is 767 days, which can be explained by follow-up visits over the course of 1 to 1.5 years.

Waiting time	Days
Min	0
Max (e.g. planned checkups)	767
Average	23
Median	4

The number of children in Sweden over a 16-year period decreased by 4% up to and including 2011 (Figure 1). In the Stockholm region, the number of children rose constantly over the same period by 16%. (Ref. specialist adviser in radiology, Stockholm County Council) (3).

Justification and referral quality

The reviewers assessed that the radiological examination was justified or probably justified in 96% of the cases, and unlikely to be justified in 4% of the cases. The percentage of assessed justification is shown by region (Figures 11, 12).

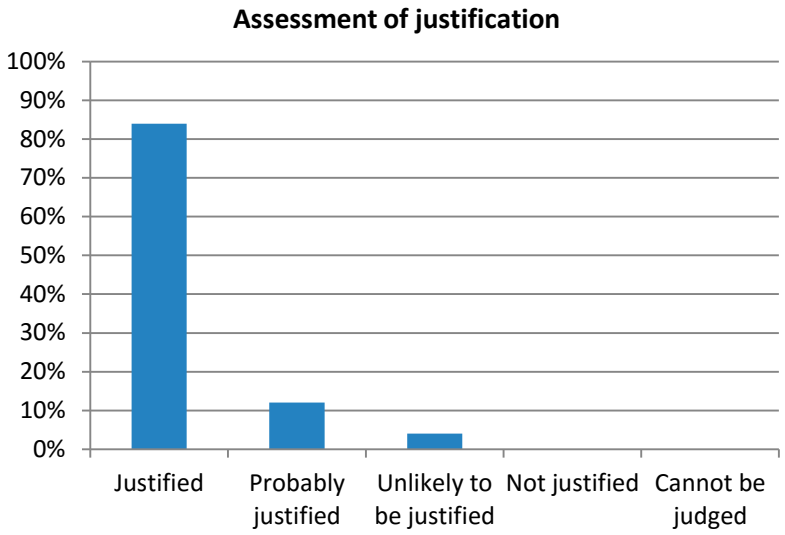

Figure 11. The reviewers' assessment of referrals in terms of justification.
Assessment by reviewers showed a very high level of justification, at 84% of the cases, and probably justified in 12% of the cases, on the basis of referral information.

The difference was marginal between regions in terms of the reviewers' assessment of justification (Figure 12).

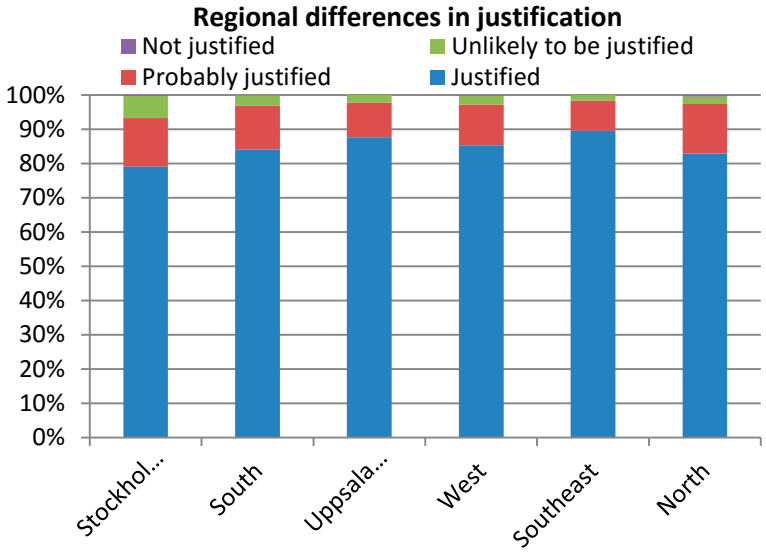

Figure 12. Percentage of reviews with assessed degree of justification, presented by region.
In percentage of reviewed referrals. Assessment by reviewers showed a high proportion of the examinations as being justified, or probably justified, on the basis of referral information. The Stockholm-Gotland region had the largest percentage of requested examinations deemed unlikely to be justi-

fied. A small number of the examinations (<1%) were assessed to be unjustified.

Referral quality was assessed as high; 96% were considered adequate or relatively adequate, 3% somewhat inadequate, and 1% inadequate. Assessed referral quality is shown by region (Figures 13, 14).

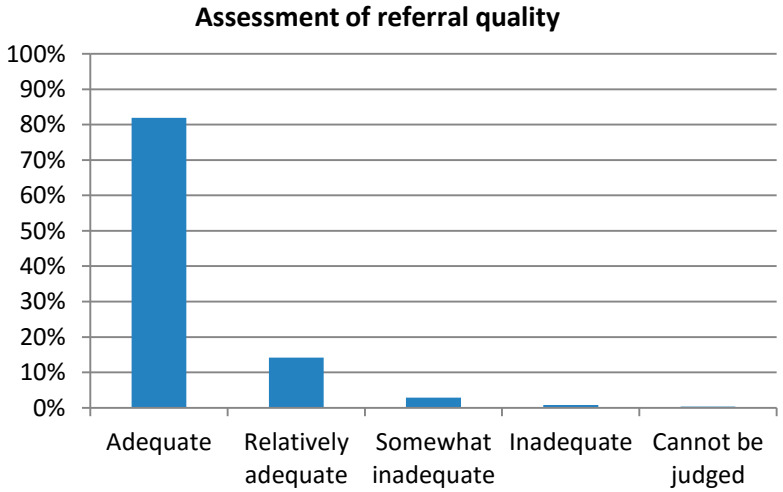

Figure 13. The reviewers' assessment of referrals in terms of referral quality.
The reviewers' assessment of referral quality showed a very high proportion of adequate referrals, at 82% of the cases, and relatively adequate referrals at 14%.

The difference was marginal between regions in terms of the reviewers' assessment of referral quality (Figure 14).

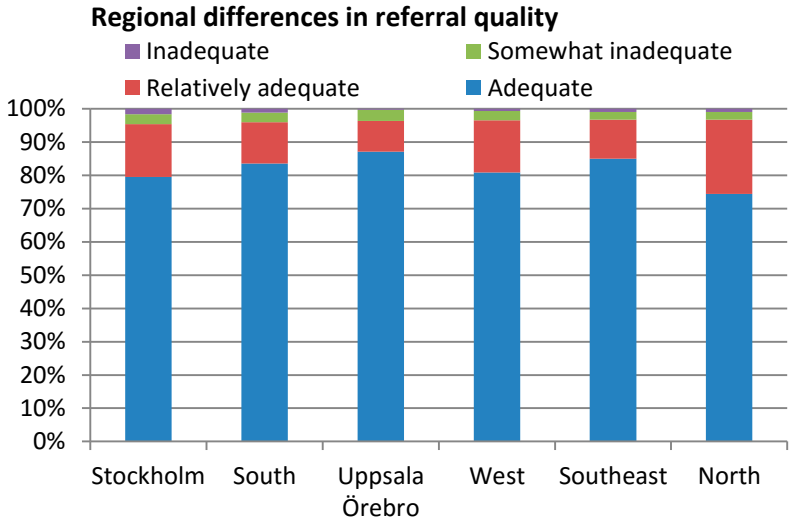

Figure 14. The reviewers' assessed referral quality by region.

In percentage of reviewed referrals. The reviewers' assessment of referral quality showed very high or relatively high referral quality on the basis of referral information. The North region shows a somewhat lower level of referral quality.

Method options: agreement and disagreement

All combinations of the requested method, performed method and method preferred by a reviewer, plus the number of reviews with each combination, are shown for CT (Table 14), MRI (Table 15), US (Table 16) and X-ray (Table 17).

Table 14. Number of reviews showing all combinations of the referring practitioners' requested CT examinations, the methods performed, and the reviewers' preferred methods. A green cell indicates a reduced radiation dose.

In only 30 reviews (2%), a method involving non-ionising radiation was chosen by the *radiologist*. On the other hand, in 324 reviews (25%), a method involving non-ionising radiation was chosen by the *reviewer.* The reviewers chose a method option without previous knowledge about the modalities available.

Requested method	Method used for examination	Method chosen by reviewer	No. of reviews
CT	CT	CT	863
CT	CT	MRI	208
CT	CT	X-ray	126
CT	CT	US	90
CT	MRI	MRI	17
CT	US	US	9
CT	MRI	CT	3
CT	US	CT	1

Table 15. Number of reviews showing all combinations of the referring practitioners' requested MRI examinations, the methods performed and the reviewers' preferred methods. A red cell indicates an increased radiation dose.

Of the MRI examinations requested by a referring practitioner, the *radiologist* chose a method *involving* ionising radiation in less than 1% of the 1,422 reviewed referrals. The *reviewers* preferred a method involving ionising radiation in 201 review cases (14%).

The reviewers chose a method option without previous knowledge about the modalities available.

Requested method	Method used for examination	Method chosen by reviewer	No. of reviews
MRI	MRI	MRI	1153
MRI	MRI	CT	120
MRI	MRI	X-ray	76
MRI	MRI	US	60
MRI	CT	CT	4
MRI	CT	MRI	5
MRI	CT	US	3
MRT	MRI	Scintigraphy	1

Table 16. Number of reviews showing all combinations of the referring practitioners' requested US examinations, the methods performed and the reviewers' preferred methods. A red cell indicates an increased radiation dose.

Of the US examinations requested by a referring practitioner, the *radiologist* chose a method *involving* ionising radiation in less than 0.3% of the 3,811 reviewed referrals. The *reviewers* preferred a method involving ionising radiation in 197 review cases (5%).

The reviewers chose a method option without previous knowledge about the modalities available.

Requested method	Method used for examination	Method chosen by reviewer	No. of reviews
US	US	US	3523
US	US	X-ray	122
US	US	MRI	79
US	US	CT	68
US	US	Scintigraphy	4
US	CT	US	7
US	CT	CT	3
US	MRI	US	2
US	MRI	MRI	1
US	US	US-guided punction	1
US	CT	MRI	1

Table 17. Number of reviews showing all combinations of the referring practitioners' requested X-ray examinations, the methods performed and the reviewers' preferred methods. A green cell indicates a reduced radiation dose.
Of the X-ray examinations requested by the referring practitioner, the *radiologist* chose a method involving reduced dose from ionising radiation in 36% of the 88 review cases. The *reviewers* preferred a method without ionising radiation in 24 review cases (27%).
The reviewers chose a method option without previous knowledge about the modalities available.

Requested method	Method used for examination	Method chosen by reviewer	No. of reviews
X-ray	CT	X-ray	28
X-ray	CT	CT	23
X-ray	US	US	18
X-ray	US	X-ray	11
X-ray	CT	US	3
X-ray	US	MRI	2
X-ray	X-ray	MRI	1
X-ray	MRI	X-ray	1
X-ray	CT	Scintigraphy	1

The reviewers agreed on the referring practitioners' chosen method, which was also used for the respective examination, as regards CT in 51% of the cases; MRI, 68%, and US, 88%, out of all the examinations performed (Tables 18, 19, Figures 15, 16, Tables 20, 21).

Table 18. The reviewers' agreement with referring practitioners and radiologists as regards the preferred method options encompassing US, MRI, CT and X-ray.
The reviewers showed a high level of agreement with the referring practitioners and radiologists when it comes to US. This suggests significant consensus when it comes to using US. The reviewers showed a lower level of agreement with the referring practitioners and radiologists when it comes to CT and MRI. This situation led to analyses of the level of agreement between reviewers vis-à-vis referring practitioners and radiologists on the part of various organ areas; see below (in the case of six examinations, the referring practitioner requested 'Other', which is not presented here).

Method	Reviewers agree No. of exams	Requested method No. of exams		Method used No. of exams	
US	1592	1816	88%	1832	87%
MRI	447	654	68%	663	67%
CT	322	628	51%	653	49%
X-ray	0	45		1	
Other 6					

The reviewers agreed on a preferred method other than the referring practitioners' chosen method, which was also the one used for the respective examination, as regards CT, 14%; MRI, 5%; and US, 2%; out of all the examinations performed (Table 19, third line, Figures 15, 16, Table 20, third line, Table 21, third line).

The reviewers had mixed preferences among the method options. At least one of the reviewers preferred the same method as the referring practitioner, which was also the one used for the respective examination, as regards CT, 30%; MRI, 24%; and US, 9%; out of all the examinations performed (CT: Table 19, second line; MRI: Table 20, second line; US: Table 21, second line, Figure 16).

Table 19. The reviewers' agreement with referring practitioners and radiologists as regards choice of the method option CT.
Line 1: The reviewers agreed among themselves and with the referring practitioners' choice of method.
Line 2: The reviewers disagreed among themselves, where at least one reviewer preferred the same method as the referring practitioner and as performed by the radiologist.
Line 3: The reviewers agreed among themselves on a different method than requested by the referring practitioner and as performed by the radiologist.
Line 4: Total number of examinations where the reviewers were in disagreement, and none of them preferred the same method as the referring practitioner or as performed by the radiologist, and the number of cases where the respective examination used a method differing from the one requested by the referring practitioner.

Compared to MRI and US, a smaller percentage agreed on using CT (51%). There was a larger percentage of reviewers who were in agreement on a different method (14%). A larger percentage of the reviewers disagreed among themselves (30%).

All examinations	No.	
CT, agreement CT (all indications)	322	51%
CT, no agreement	187	30%
CT, agreement on not using CT	91	14%
Other	28	4%

Table 20. Agreement data for MRI; quantity and percentage.
Little agreement on not performing MRI (5%). A significant percentage of examinations where the reviewers were in disagreement (25%).

All examinations	No.	
MRI, agreement MRI (all indication	447	68%
MRI, no agreement	160	25%
MRI, agreement on not using MRI	35	5%
Other	12	2%

Table 21. Agreement data for US; quantity and percentage.
Very high level of agreement on performing US (88%). Very little agreement on performing a method other than US (2%).

	All US No. of exams		2 years and older No. of exams	
US, agreement US	1592	88%	944	87%
US, no agreement	170	9%	102	9%
US, agreement on not using US	40	2%	26	2%
Other	14	1%	9	1%

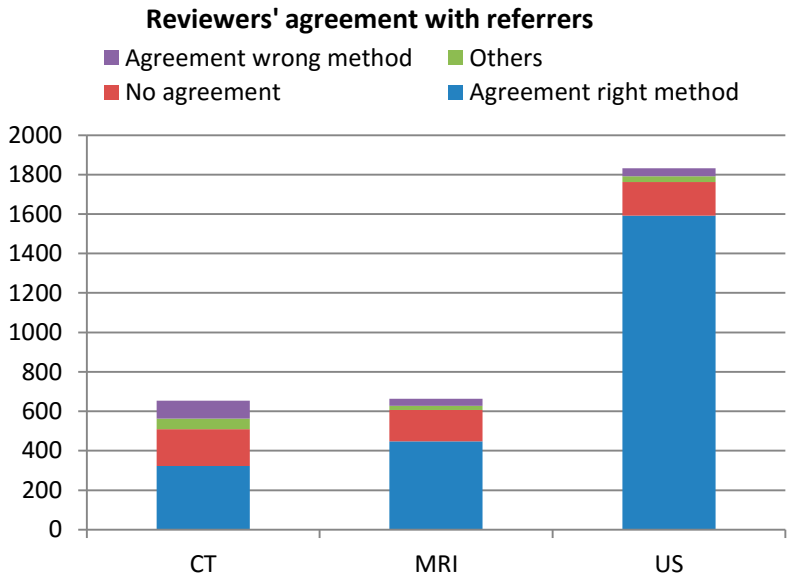

Figure 15. Agreement data; quantities for all methods.
Considerable agreement on US as the preferred method; little agreement on CT according to the reviewers.

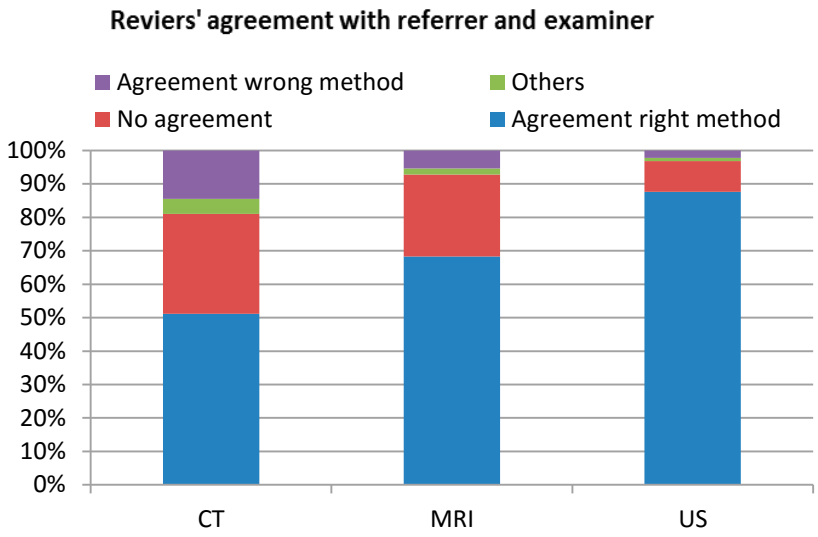

Figure 16. Agreement data; percentages for all methods.
High level of agreement for US (88%), less agreement on MRI (68%), least agreement on CT (51%). The highest level of agreement among the reviewers on not performing CT (14%). Little agreement on not performing MRI (5%). Very little agreement on not performing US (2%).

Outcome for CT: regional quantities and percentages

The reviewers agreed among themselves with the referring practitioners' respective choice of method, i.e. = the used method of CT, from the lowest level of 43% (West) to the highest level of 57% (South) (Figures 17, 18).

The reviewers agreed among themselves on a preferred method option that was not CT, where CT had been chosen by the referring practitioner, i.e. = the method used, from 10% (Stockholm-Gotland) to 24% (Southeast) (Figures 17, 18).

The reviewers showed internal disagreement. At least one of the reviewers preferred CT, where CT had been chosen by the referring practitioner, i.e. = the method used, from 15% (Southeast) to 37% (Stockholm-Gotland) (Figures 17, 18).

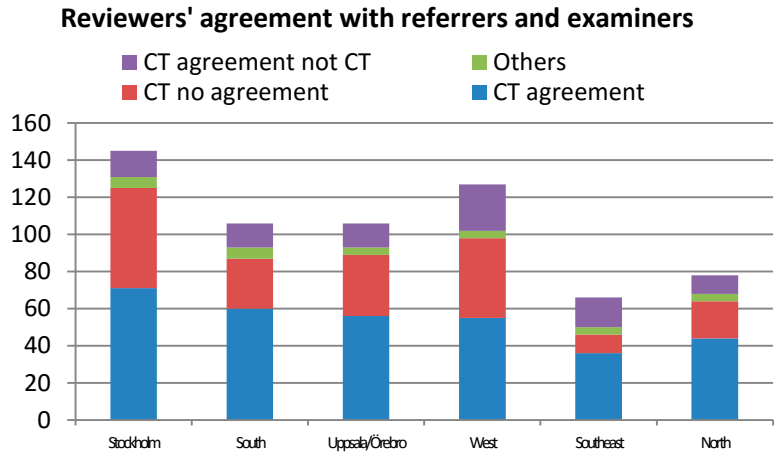

Figure 17. Agreement data for CT. Quantities by region.

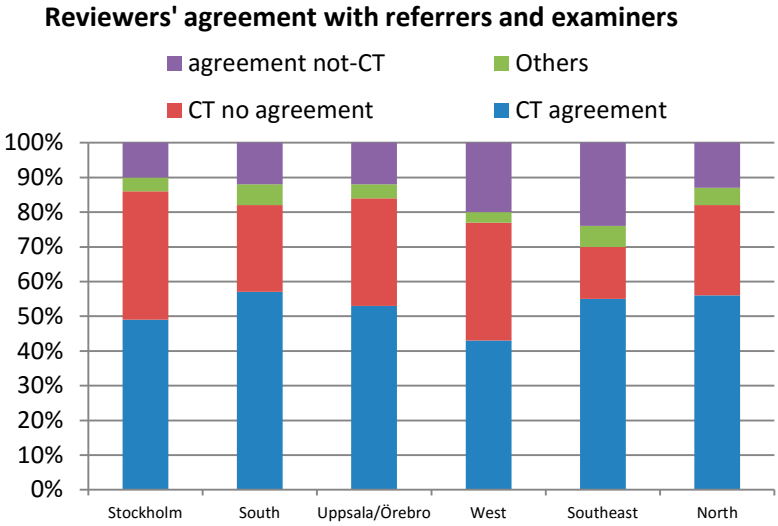

Figure 18. Agreement data for CT. Percentages by region.
The highest level of agreement (blue) on performing CT in the South region, the lowest level in the West. The highest level of agreement on not performing (purple) CT in the Southeast and the lowest level in Stockholm-Gotland.

Outcome for MRI: regional percentages

The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, MRI, from 59% (Southeast) to 79% (West) (Table 20, Figures 19, 20).

The reviewers agreed among themselves on preferring a method option that was not MRI, where MRI had been chosen by the referring practitioner, i.e. = the method used, from 3% (West) to 13% (South) (Table 20, Figures 20, 21).

The reviewers showed internal disagreement. At least one of the reviewers preferred MRI, i.e. = the method used, from 17% (West) to 32% (Southeast) (Table 20, Figures 19, 20).

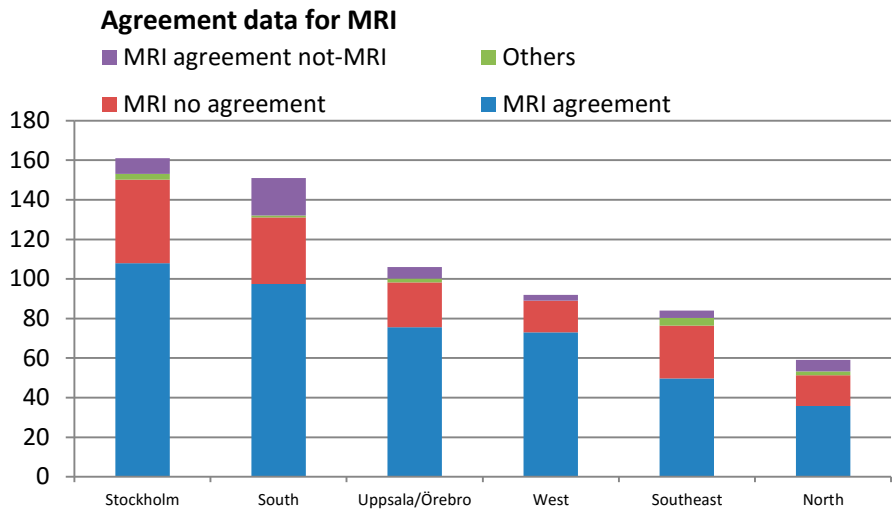

Figure 19. Agreement data for MRI examinations by region

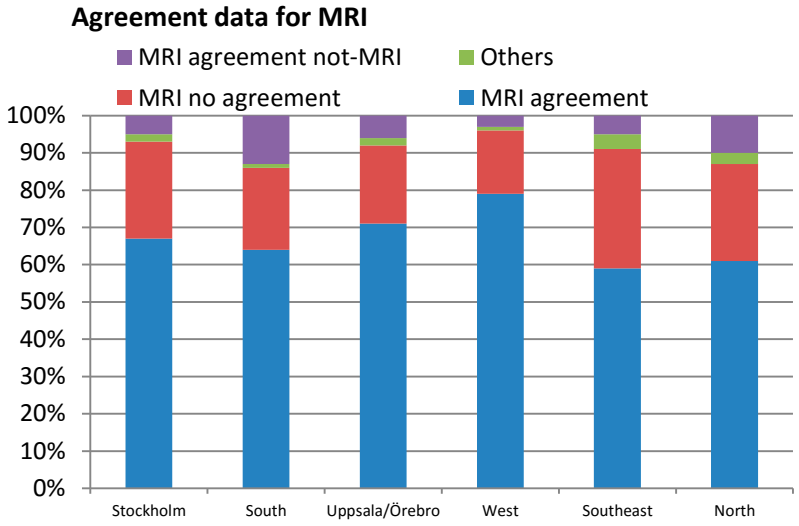

Figure 20. Agreement data for MRI. Percentage of examinations by region.

Comment

The highest level of agreement (blue) on performing MRI in the West region, lowest level in the Southeast. The highest level of agreement on not (purple) performing MRI in the South region, and the lowest level in the West region.

The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, US, in 88% of the cases.

The reviewers agreed among themselves on preferring a method option that was not US, where US had been chosen by the referring practitioner, i.e. = the method used, in 2% of the cases.
The reviewers showed internal disagreement. At least one of the reviewers preferred US, where US had been chosen by the referring practitioner, i.e. = the method used, in 9% of the cases (Figure 16, Table 21).
The reviewers preferred an examination reducing radiation dose in 399 of the reviewed cases and a method raising the radiation dose in 489 of the reviewed cases, out of a total of 6,656 reviewed cases (Tables 14, 15, 16, 17).

Outcome: brain/skull and region

The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, CT of brain/skull, from 34% (West) to 68% (Southeast) (Figures 22, 23).
The reviewers agreed among themselves on preferring a method option other than the referring practitioner's choice, i.e. = the method used, CT of brain/skull, from 9% (Stockholm-Gotland) to 32% (West) (Figures 21, 22).

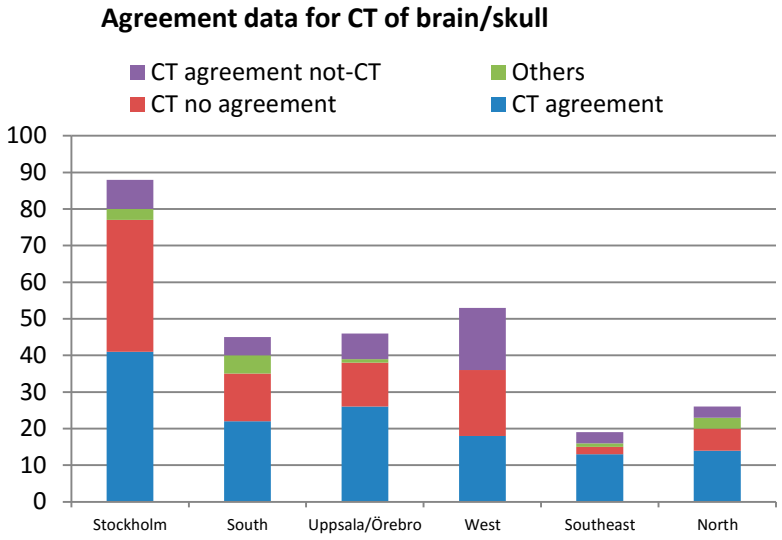

Figure 21. Agreement data for CT of brain/skull. Quantities by region.

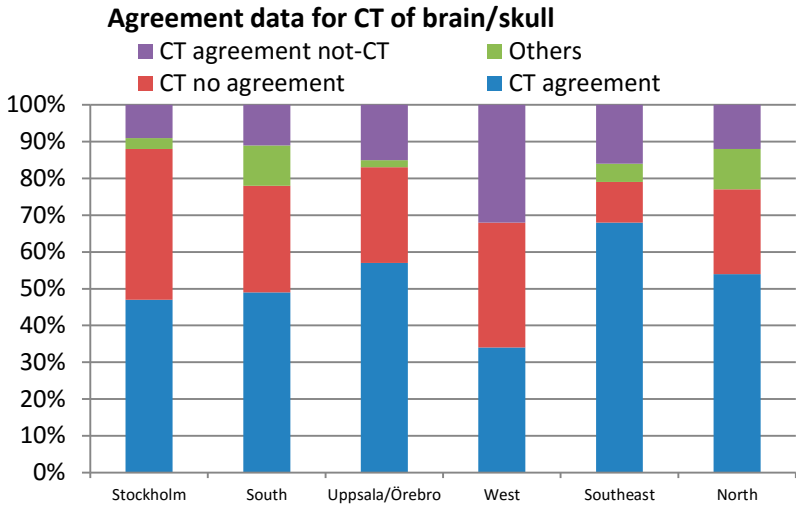

Figure 22. Agreement data for CT of brain/skull. Percentages by region. The highest level of agreement on performing CT was shown by the South-east region, with the lowest level of agreement shown by the West region. The highest level of agreement on not performing CT was shown by the West region, with the lowest level of agreement shown by Stockholm-Gotland.

Outcome: CT of brain/skull

The brain/skull is the most common organ area for CT at 42% of all CT examinations.
The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, CT of the brain/skull, in 48% of the cases.
The reviewers agreed among themselves on preferring a method option other than the referring practitioner's choice, i.e. = the method used, CT of brain/skull, in 16% of the cases.
The reviewers showed internal disagreement. At least one of the reviewers preferred CT of the brain/skull, where CT had been chosen by the referring practitioner, i.e. = the method used, in 31% of the cases (Table 22).

Table 22. Agreement data for CT of brain/skull, quantities and percentages.
Lower level of agreement on performing CT (48%) and higher level of agreement among the reviewers on a method other than CT (16%) in relation to agreement data for all CT examinations.

Brain/skull	No.	
CT agreement	133	48%
CT no agreement	86	31%
Other	44	16%
Agreement not CT	14	5%

Outcome: MRI of brain/skull

The brain/skull is the most common organ area for MRI at 47% of all MRI examinations.
The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, MRI of the brain/skull, in 77% of the cases.
The reviewers agreed among themselves on preferring a method option other than the referring practitioner's choice, i.e. = the method used, MRI of brain/skull, in 6% of the cases.
The reviewers showed internal disagreement. At least one of the reviewers preferred MRI of the brain/skull, where MRI had been chosen by the referring practitioner, i.e. = the method used, in 16% of the cases (Table 23).

Table 23. Agreement data for MRI of brain/skull. Quantities and percentages.
There was considerable agreement among the reviewers on performing MRI of the brain/skull (77%), with a slightly higher percentage of the reviewers agreeing on preferring a method other than MRI.

Brain/skull	No.	
MRI agreement	235	77%
MRI no agreement	50	16%
Other	18	6%
Agreement not MRI	2	1%

Outcome: US of brain/skull
The organ area brain/skull had 138 US examinations, corresponding to 7.5% of all US examinations.
The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, US of the brain/skull, in 82% of the cases.

The reviewers agreed among themselves on preferring a method option other than the referring practitioner's choice, i.e. = the method used, US of brain/skull, in 4% of the cases.
The reviewers showed internal disagreement. At least one of the reviewers preferred US of the brain/skull, where US had been chosen by the referring practitioner, i.e. = the method used, in 13% of the cases (Table 24).

Table 24. Agreement data for US of brain/skull. Quantities and percentages.
A comparison of agreement data for all US showed a somewhat lower level of agreement among the reviewers on US of the brain/skull, with a higher percentage of the reviewers agreeing on preferring a method other than US.

Brain/skull	No.	
US agreement	112	82%
US no agreement	17	13%
Other	5	4%
Agreement not US	2	1%

Outcome: CT of abdomen/pelvis

The organ area abdomen/pelvis had 58 CT examinations, corresponding to 8.9% of all CT examinations.

There were regional differences. The number of examinations was small in each outcome category. Consequently, the outcome is inconclusive.

The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, CT of abdomen/pelvis, in 13 out of 53 cases.
The reviewers agreed among themselves on preferring a method option other than the referring practitioner's choice, i.e. = the method used, CT of abdomen/pelvis, in 16 out of 53 cases.

Table 25. Agreement data for CT of abdomen/pelvis. Quantities and percentages.
A comparison of agreement data for all CT showed a substantially lower level of agreement among the reviewers on CT of the abdomen/pelvis, with a considerably higher percentage of the reviewers agreeing on preferring a method other than CT. Note that the number of examinations is low, resulting in insufficiently reliable representativeness.

Abdomen/pelvis	No.	
CT agreement	13	25%
CT no agreement	17	32%
Other	16	30%
Agreement not CT	7	13%

Outcome: MRI of abdomen/pelvis

The organ area abdomen/pelvis had 35 MRI examinations, corresponding to 5.3% of all MRI examinations.

Outcome: US of abdomen/pelvis

Examination of the abdomen/pelvis is the most common organ area for US at 34% of all US examinations.
The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, US of abdomen/pelvis, in 88% of the cases.
The reviewers agreed among themselves on preferring a method option other than the referring practitioner's choice, i.e. = the method used, US of abdomen/pelvis, in 3% of the cases.
The reviewers showed internal disagreement. At least one of the reviewers preferred US of the abdomen/pelvis, where US had been chosen by the referring practitioner, i.e. = the method used, in 8% of the cases (Table 26).

Table 26. Agreement data for US of abdomen/pelvis. Quantities and percentages.
A comparison of agreement data for all US showed the same level of agreement among the reviewers on preferring US of the abdomen/pelvis, with a somewhat higher percentage of the reviewers agreeing on preferring a method other than US.

Abdomen/pelvis	No.	
US agreement	550	88%
US no agreement	52	8%
Other	17	3%
Agreement not US	5	1%

Outcome: CT of kidneys/urinary tract

The organ area kidneys/urinary tract had 3 CT examinations, corresponding to 0.5% of all CT examinations.

Outcome: MRI of kidneys/urinary tract

The organ area kidneys/urinary tract had 1 MRI examination, corresponding to 0.2% of all MRI examinations.

Outcome: US of kidneys/urinary tract

The organ area kidneys/urinary tract had 477 US examinations, corresponding to 26% of all US examinations.
The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, US of kidneys/urinary tract, in 93% of the cases.
The reviewers showed internal disagreement. At least one of the reviewers preferred US of the kidneys/urinary tract, where US had been chosen by the referring practitioner, i.e. = the method used, in 5% of the cases (Table 27).

Table 27. Agreement data for US of kidneys/urinary tract. Quantities and percentages.
A comparison of agreement data for all US showed a higher level of agreement among the reviewers on preferring US of the kidneys/urinary tract, with only 1 examination where the reviewer agreed on preferring a method other than US. There was a markedly lower percentage of examinations where the reviewers were in disagreement. The overall conclusion is that the level of national consensus is very high as far as concerns US of kidneys/urinary tract.

Kidneys/urinary tract	No.	
US agreement	442	93%
US no agreement	23	5%
Other	1	0%
Agreement not US	8	2%

Outcome: pelvis/hip joints

Table 28. Agreement data for US, MRI and CT of pelvis and hip joints. Quantities and percentages for US.
A comparison of agreement data for all US showed a lower level of agreement among the reviewers on preferring US of the pelvis and hip joints, with a somewhat higher percentage of the reviewers agreeing on preferring a method other than US. Few MRI and CT examinations of the pelvis and hip joints were performed; consequently, their application cannot be assessed.

Pelvis/hips	No.	
US agreement	190	81%
US no agreement	37	16%
Agreement not US	7	3%

Pelvis/hips	No.
MRI agreement	9
MRI no agreement	7
Agreement not MRI	2

Pelvis/hips	No.
CT agreement	3
CT no agreement	7
Agreement not CT	1

Outcome: CT of joints and soft tissues

The organ area joints and soft tissues had 50 US examinations, corresponding to 7.7% of all CT examinations.

Outcome: MRI of joints and soft tissues

The organ area joints and soft tissues had 168 MRI examinations, corresponding to 25.5% of all MRI examinations.

Table 29. Agreement data, quantities of MRI examinations of joints/soft tissues.
Line 1: The reviewers agreed among themselves and with the referring practitioners' respective choice of method, the same one as the examination performed.
Line 2: The reviewers disagreed among themselves, where at least one reviewer preferred the same method as the referring practitioner and radiologist.
Line 3: The reviewers agreed among themselves on a different method than requested by the referring practitioner and radiologist.

In 37% of the cases, at least one reviewer assessed that some other, alternative examination should be performed.

Joints/soft tissues	No.	
MRI agreement	102	61%
MRI no agreement	53	32%
Other	9	5%
Agreement not MRI	4	2%

Outcome: US of joints and soft tissues

The organ area joints and soft tissues had 127 US examinations, corresponding to 6.9% of all US examinations.

Outcome: CT specialty

The reviewers agreed among themselves on the referring practitioners' respective choice of method, i.e. = the method used, from 21% (orthopaedics) to 84% (jaw surgery).
The reviewers agreed among themselves on preferring a method option other than the referring practitioner's choice, i.e. = the method used, from 28% (orthopaedics) and 22% (general medicine) to 3% (ears, nose, throat) (Figure 23).

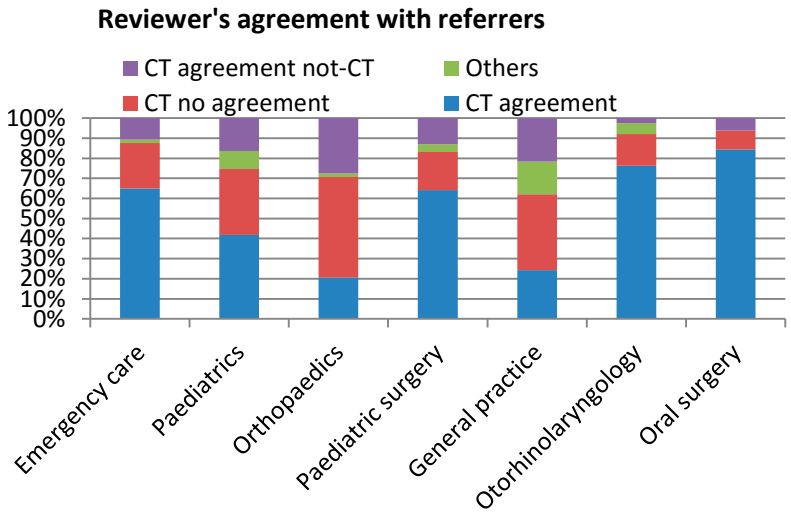

Figure 23. Agreement data for CT. Percentages, grouped by specialty. The highest percentage of reviewers who were in agreement on preferring an examination other than CT was in the specialties orthopaedics and general medicine.

Questionnaire

Out of the 78 departments that perform paediatric examinations, 13 of them lack access to MRI and 4 lack access to US.

Protocols (care programmes) for radiological examinations of children aged 0–15 are in place at 70 out of 72 departments that perform paediatric examinations (97%). There was access to general anaesthesia at 37 out of 72 departments (51%). There was dose reduction software at 45 out of 72 departments (63%) (Table 30, Figure 24).

Table 30. Summary of questionnaire survey of 72 paediatric departments. Protocols, general anaesthesia and dose reduction software.
In terms of general anaesthesia, 51% is an indication that half of all departments offering MRI are unable to examine children under around 6 years of age.

72 departments perform paediatric examinations		
Documented examination protocols	70	97%
General anaesthesia	37	51%
Dose reduction software	45	63%

Table 31. Dose reduction software: suppliers.
Siemens' system is the most prevalent.

Dose reduction software	
Siemens Care Dose	20
GE ASIR, smart mA	9
PHILIPS ACS	8
Toshiba	4
Auto mA	3

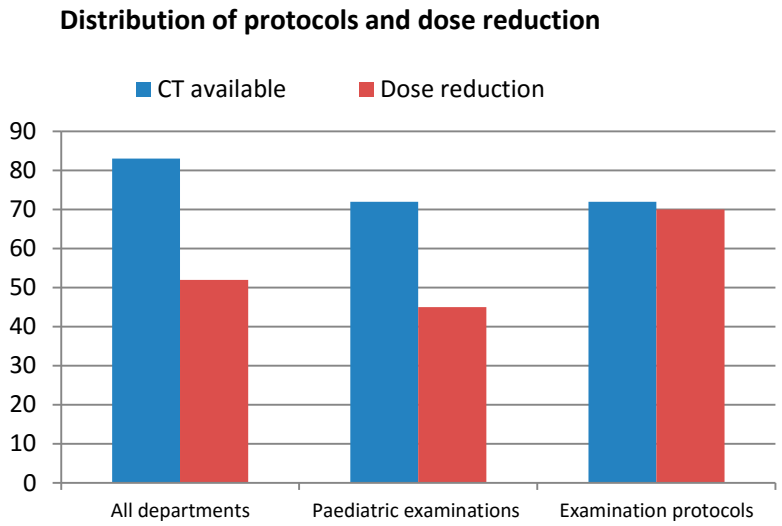

Figure 24. Survey outcome of distribution of protocols and dose reduction software at all departments.
CT equipment is available at 83 diagnostic imaging departments, of which 52 have dose reduction software. 72 departments perform paediatric examinations; 45 of these departments have dose reduction software. 70 out of 72 departments have complete or partial protocols.

MRI equipment density per million residents was lower in the South and West regions than in the other regions. CT equipment is relatively evenly distributed (Table 32).

Table 32. Survey outcome of MRI and CT equipment density per million residents, by region.
The lowest MRI equipment density per million residents is shown by the West region, with the lowest CT equipment density shown by Stockholm-Gotland.

	No. MRI	No. CT	No. MRI per million inhabitants	No. CT per million inhabitants
Stockholm	39	39	18.5	18.5
South	25	35	14	19.9
Uppsala/Örebro	29	39	14.7	19.8
West	24	38	13.9	22
Southeast	18	22	18	22
North	14	18	16	20.5

7. Discussion

Therapy and diagnostics

Diagnostic measures differ from therapeutic measures.

A population that undergoes a *diagnostic measure* is by definition heterogeneous. “Heterogeneous” implies that it is not known in advance which members of the population of individuals with a suspected illness in actual fact have, or do not have, the illness in question. Alternatively, the extent of an illness is not known in advance (e.g. spread of tumours and division into stages, or the possible existence of metastases).

The population of patients *being treated for a specific illness* has (or is expected to have) a very high frequency of the illness in question. This requirement implies a need for accurate diagnosis, not only for identification, but also for subclassification and determination of spread.

Diagnostic measures may have the following objectives:

1) Ruling out the possibility of a treatable serious disease is an important principle, particularly because there is a general shift towards more effective treatment methods and a delayed diagnosis can mean the difference between cure and death. Even in the most experienced medical hands, diagnosis can be delayed by unexpected and uncommon diseases with an unusual pattern of symptoms. It is not uncommon for serious diseases to be discovered by accident.

2) Pre-therapeutic diagnostics for selecting and planning treatment may presuppose several diagnostic measures. Correct, individually adapted treatment may presuppose subclassification, assessment of spread, extent or stage, as well as determination of underlying genesis. For this reason, several additional diagnostic measures are often required. Diagnostic measures and treatment options are nowadays often thoroughly prescribed by care programmes and guidelines.

3) Follow-ups of treatment with a diagnostic measure are based on experience from treatment outcomes, relapse frequency and variations in points in time for relapses of a treated disease. Adequate guidelines on appropriate follow-up intervals presuppose a compilation of long-term follow-ups of outcomes on the part of patients with the disease in question. The interval and kind of examination

are also defined by other illnesses that the patient is suffering from. When it comes to many common and uncommon diseases, long-term follow-ups have been studied and published on a scientific basis. Guidelines and care programmes are based on these kinds of scientific compilations. However, deviations from guidelines are not uncommonly based on the individual patient's illness and the experience of the physician in charge.

Justification

Justification is defined on the basis of two principles:

1) The definition is a general one that is applicable to all diagnostic testing. In the current "Referral guidelines for imaging" (EU, 2000), justification is defined as follows: "A valuable examination is characterised by the outcome–positive or negative–implying a change to the treatment or contributing towards confirming the physician's diagnosis".

2) One theoretical framework defines six quality levels, where on each level, cost-effectiveness and estimated benefits versus risk can be assessed for a given diagnostic test. Justification as per the general definition, for example, the definition contained in EU guidelines, implies the examination needing to achieve level 3 or 4 according to Fryback and Thornbury (14) (Figure 25).

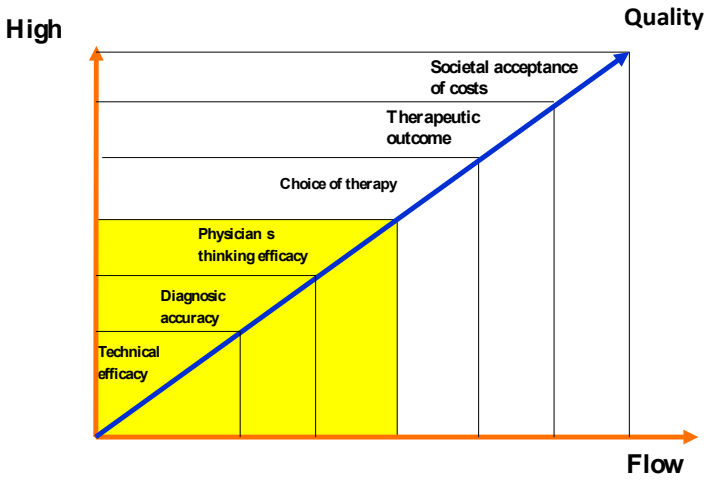

Figure 25. Quality levels according to Fryback and Thornbury. A diagnostic level of at least three is required for clinics' selection of therapy.

The second definition of justification as defined by SSM's regulations in the context of patients is as follows (8):

> A judgement according to which a medical exposure gives a benefit to the patient that, with respect to the diagnostic information or the therapeutic result, exceeds the estimated detriment caused by the exposure, also taking into account the efficacy, the benefits and the risks of other existing methods implying a smaller radiation dose, or not using ionising radiation at all.

Justification of examination methods giving a radiation dose, such as CT, is by this definition dependent on the possibility of choosing other alternative diagnostic imaging methods. For a given clinical question, an alternative method without implying radiation dose (for example, MRI and US) is to be selected, provided that the diagnostic accuracy of the alternative method is at the same high level as when using CT (or a sufficiently high level for the question). This principle applies with the exception of when a planned treatment, such as radiotherapy, implies the diagnostic radiation dose giving an irrelevant contribution.

The significance of considering alternative methods to CT depends on the expected radiation dose. For example, CT of a wrist gives negligible exposure, and low dose CT of the nasal cavity and sinuses gives a very low estimated whole body dose. In these cases, there is little justification to consider alternative methods not giving a radiation dose; while in connection with examinations giving a higher radiation dose, such as CT of the abdomen, CT of the chest-upper spine/lumbar region, or CT of the brain, it is more important to consider alternative methods. The need to consider alternative options to CT not resulting in a radiation dose, first and foremost when it comes to the brain and thorax/abdomen, has been underlined by a recently published 10-year follow-up of 180,000 CT examinations of children in the United Kingdom (7). During the 10-year period, there was an occurrence per 10,000 individuals of one additional case of leukaemia and one additional case of a brain tumour compared with the control group.

An assessment of benefit/risk is to be weighed in relation to the risks of alternative method options. When considering an MRI scan of (for example) the skull/brain of an infant, an individual assessment should be made of the risk of anaesthesia in relation to the future risk posed by a radiation dose from CT. See also the discussion section on referral quality and justification below, in addition to the discussion on this study's findings.

Design of this study

Method selection

In this study, the reviewers were not informed about the actual examination performed. Instead, they were to indicate their personal choice of preferred method: CT, MRI, US or X-ray examination, or other preferred method on the basis of the referral content. All referral information that could be used to deduce which method was performed was de-identified. The advantage of this design was to present not only in the findings the level of disagreement among reviewers, but also the extent to which the reviewers showed agreement or disagreement with the referring practitioners' respective choice of method and the respective method used for the examination. In this respect, the design of this study was in contrast to that of the national survey on use of CT in Sweden (Report 2009:3) (1). Thus, as a consequence, this implied a key difference, namely how relative consensus and dissent between the respective referring practitioner, radiologist and reviewer are accounted for and presented.

The disadvantage of the design was that the reviewers, as opposed to in the previous study, could not adopt a particular standpoint on the referring practitioner's choice of method and the respective method chosen for the examination actually performed. This excluded the option of assessing the respective requested and performed CT examination as unjustified, and instead meant indicating a different preferred method.

On the whole, we are of the view that de-identified method choices have more advantages than disadvantages. The outcome of the reviewers' preferred alternative methods lacked bias in that the reviewers could not be influenced by the requested or de facto method selected. Assessing justification was replaced by a general assessment of the extent to which diagnostic imaging might be justified at all.

The time period of the study and examination quantities

This study covers all CT, MRI and US examinations of children at medical imaging and functional diagnostics departments (previously referred to as radiology departments) performed throughout Sweden over a 14-day period in March to April 2011.

The period of the study was chosen based on the assumption that all medical care departments ran complete clinical services during the period. The intention was to collect referrals and examination results for approximately 3,000 CT, MRI and US examinations. This estimated quantity proved to be adequate at 3,149 collected referrals. In addi-

tion, a sufficient number of examinations were achieved in each of the subcategories: medical care regions, examined organ areas, level of medical care, gender and age, and a sufficient number of examinations using all three methods. US predominated with a distribution of 2.7:1:1 (US, CT and MRI, respectively). The number of CT and MRI examinations encompassed was assessed as adequate for judging outcomes when comparing between medical care regions, care levels and the most commonly examined organ areas plus referrers' specialties.

Representativeness

It is advantageous to include all examinations (or observations) carried out over a period of time that is not too long. Studies over extended periods of time risk becoming biased, as there is increased probability of guidelines or care programmes undergoing changes during the period studied on national, regional or local level. The period studied was assessed as representative for the entire year.

Reviewing physicians

This kind of comprehensive review of referrals should presuppose the reviewing physicians being experienced clinical specialists. All the reviewers had direct links to paediatric and adolescent medicine, with the exception of one reviewer who is a practicing clinic director with extensive experience. Apart from required professional skills, additional requirements could also have been defined for the reviewers: to have undergone updates on national and regional guidelines in order to determine whether a requested examination met the guidelines.

However, it transpired during the recruitment process that documented regional guidelines are frequently in place, but that there is largely a lack of documented national guidelines. This was one rationale behind not imposing formal requirements on access to the six regions' guidelines. A more important rationale was the study having the aim of studying medical services under routine conditions, with a special focus on the level of agreement in assessments, and not seeking to measure deviations in medical care carried out under optimal conditions.

Instead, the reviewers adopted a standpoint based on their extensive clinical experience and relevant clinical practices. Even without particular requirements on updates, the reviewers might hypothetically be assumed to have a considerable level of consensus, based on the fact that paediatric care in Sweden is of limited size. In at least three medical care regions, paediatric care is dominated by major regional centres, such as Astrid Lindgren Children's Hospital with satellites in Stockholm, the Queen Silvia Children's Hospital in Gothenburg, and

paediatric clinics at Skåne University Hospital in Lund. There are several national professional societies in paediatric care, including the Swedish Society of Paediatric Radiology. Despite the lack of documented national guidelines, likely a consequence of national and shared international professional contacts, regional guidelines ought to be harmonised. As each examination was assessed by at least two reviewers, in most cases representing various medical care regions, the level of agreement/disagreement in the assessments could hypothetically represent a measure of the level of national consensus. See also the discussion section below, "Reviewing referrals: agreement and disagreement".

Material collection and review work

Collecting and reviewing referrals is a practical and relatively straightforward approach to studying the use of diagnostic testing in medical care. A referral for diagnostic testing happens to be the only essential document for such testing, and the information contained in the referral not only directs method selection, but also technical execution, etc.

Once referral details have been entered in a database, it is possible to quickly produce statistics on examinations performed and to compare differences between areas such as medical care regions, outpatient and inpatient care, etc. Allowing the reviewers to personally enter their assessments in individually adapted databases is not only efficient, it can also prevent incorrect sourcing. On the other hand, this method is not suitable for studying applied treatment measures in health and medical services. These kinds of studies are more complex and include longitudinal follow-ups of treated patients. As opposed to using diagnostic testing, treatment measures cannot be studied based on a "snapshot in time". One example of studying treatment and comparing between treatment clinics is involvement in any of the relatively numerous national quality databases established in Sweden.

Referral quality and justification

An assessment of referral quality and justification is based on the defined quality levels 1 to 6 according to Fryback and Thornbury (14), where justification is based on levels 3 and 4 (Figure 25). The concept of efficacy was used here as a part of the review of referral quality.

Based on the referral information, an account is provided of efficacy as a required technical capability (level 1) and diagnostic accuracy, that is, factors such as sensitivity, specificity, predictive values and others (level 2) implied by the clinical question.

Different requirements are imposed for diagnostic testing depending on the question. In some cases, very high sensitivity is decisive when avoiding false negatives is the ambition, when future consequences might be decisive for curative or palliative treatment when, for instance, treating previously undiagnosed malignancy (e.g. a missed malignant tumour from curatively treatable to palliative treatment with a poor prognosis). In these cases, one accepts what is often statistically unavoidable, in other words that high sensitivity implies lower specificity, thus a higher percentage of false positives. In its turn, this implies the need for further diagnostic measures in order to, during the next step, separate the true positives from the false positives through the first test. Often, the main focus varies in connection with these supplementary diagnostics: now it is important to, through a high level of specificity, identify the true negatives among the false positives from the first test.

Technical capability (level 1) is also important. The possibility of using referral information for assessing effectiveness, defined as required technical capability, implies the referral recipient being able to decide on not only the method(s) that can provide accurate imaging of the part of the body in question, but also the procedure to be used.

If the referral lacks information to an extent preventing assessment of effectiveness, it is impossible to determine the optimal examination method and optimal examination procedure.

Thus, a high level of referral quality is crucial for enabling the referral recipient to determine independently of the referring practitioner whether the question truly presupposes use of CT, or whether it is sufficient to use a different method giving a lower radiation dose, or no dose whatsoever.

Obviously, a high level of referral quality is also a prerequisite to enable the referral recipient to determine from the referral information whether the examination outcome may be expected to have a bearing on management or therapy, or alternatively, give an accurate diagnosis–and thus be justified.

Reviewing referrals: agreement and disagreement

Each referral was examined by a minimum of two independent reviewers. A small percentage of the referrals were examined by three reviewers; a small number of referrals were examined by four reviewers. The study's design implied that the level of agreement among reviewers could be evaluated, in addition to the level of agreement of the reviewers with the respective referring practitioner's choice of method and the respective method of examination actually performed

on each patient. An evaluation of the cases upon which the reviewers were in disagreement showed a considerable proportion of them with at least one reviewer (1 out of 3, 2 out of 3 or 1-3 out of 4) in agreement with the referring practitioner's and the examining radiologist's choice.

The reviewing physicians were selected as persons who were clinically experienced and recognised as having skills integrated with extensive and proven experience and, as reviewers, in accordance with generally accepted guidelines. The study reflects routine medical care that contrasts against optimal conditions in each individual case.

An interpretation of agreement and disagreement is based on differences between medical services carried out under optimal conditions (efficacy) and medical services carried out in routine circumstances (effectiveness). Clinical trials often presuppose ideal conditions that are identical for all the patients encompassed. This study, which evaluates use of medical services, conducts an analysis of routine medical care.

The category of "other outcomes" consisted not only of examinations performed using a method other than the one requested by the referring practitioner, but also of examinations performed using the same method as requested by the referring practitioner and the one actually performed, and where the reviewers disagreed among themselves while at the same time showing disagreement with the respective referring practitioner/radiologist in terms of the method chosen.

Changes in examination method from the referring practitioner's request were infrequent. Total disagreement among reviewers and vis-à-vis the referring practitioner/radiologist was also uncommon. In combination, the category "other outcomes" generally constituted a small percentage of the examinations.

One feasible component of the design could have been requiring the reviewers to have broad expertise in currently applicable care programmes and guidelines, not only internationally and nationally, but also regionally. In this way, the reviewers' assessments would be viewed as grades on the extent to which the reviewed examinations were in compliance with care programmes and guidelines. It would have been very difficult to gain acceptance for such stringent demands on the reviewers. It was also assessed as very difficult to compile information on all the regional care programmes and guidelines.

Differences in outcomes between the examination methods should be interpreted as a measure of the degree of consensus on a national level. For example, the very high level of agreement in terms of the choice of US suggests a high degree of national professional consen-

sus on the indications for and use of US on children. On the other hand, there is apparently no equivalent high degree of national consensus on how and when to use CT on children.

This may be interpreted as a relatively large-scale lack of national consensus, more in terms of method selection, and perhaps less in terms of an indication for any type of diagnostic imaging examination. It was also stated in this study that the examinations in a very high percentage of the cases reviewed were justified, or probably justified.

The study suggests a possible need in paediatric care for more thorough guidelines, above all for the choice between CT and MRI, US or other method implying lower radiation dose, where the focus is on effectiveness meeting requirements for technical capability and diagnostic accuracy by using an alternative method to CT.

8. Conclusions

Age and gender

As anticipated, no difference was found between girls and boys in the number of performed examinations. A comparison between genders in terms of assessing referral quality, justification, agreement and disagreement vis-à-vis method choices is not presented in this report; however, no difference was demonstrated.

The distribution of CT, MRI and US between age categories showed a desirable evolution in US as the predominant method for ages 0-2. For children ages 2-15, there was a decrease in use of US with older age category, whereas the use of CT and MRI rose gradually up to age 15 (Figures 3, 4, 6).

Referral quality, justification and level of medical care

A high level of referral quality is of particular importance when requesting imaging of children in general and, especially for cross-section diagnostic imaging, mainly CT and MRI.

In this study, the reviewers assessed that 96% of the referrals were adequate or relatively adequate, and that 4% of the referrals were inadequate (Figures 13, 14). At the hospitals, very few referrals were assessed as inadequate, while 2% to 3% were assessed as being relatively inadequate. Consequently, the quality of referrals was assessed as high for a very high percentage of them, and the level of bias when assessing justification due to inadequate referrals can be assumed as negligible.

One reason behind low referral quality may be that the clinical information is stated briefly if an examination is discussed during rounds or a clinical conference, or is supplemental to a previous examination. In this study, according to the reviewers, these potential sources of inferior referral quality did not occur.

A somewhat higher percentage of referrals from outpatient care were relatively inadequate (6%-7%). This difference between hospitals and outpatient care was also demonstrated by earlier studies of CT use in Sweden in 2006 (1) and of MRI use in Stockholm County in 2001 and 2004 (15). In these studies as well, the quality of referrals was high at university hospitals and county hospitals.

Assessments of justification followed the same pattern as in the previous studies, where a very high percentage of the referrals from univer-

sity hospitals and county hospitals were assessed as being justified, while the level of justification was deemed lower for examinations requested by specialists and general practitioners in outpatient care.

The outcome of the study may be deemed to demonstrate partial covariance with the frequency of examinations in care levels. Referrals from outpatient care comprised 19% of examinations in the Stockholm region, in contrast to 7% in the North region (Figure 10). Examinations requested by hospitals and outpatient care in Stockholm County showed the following: a higher percentage of inadequate and relatively inadequate referrals; a higher percentage of referrals that were deemed unlikely to be justified and deemed as unjustified; and referrals from outpatient care that could not be assessed; that is, the same trend observed in previous studies.

Proposed measures

Paediatric care in Sweden is to a large extent concentrated to a small number of departments, particularly in terms of treating serious and chronic diseases. An additional factor is that Stockholm and Gothenburg have dedicated hospitals for paediatric care, also with significant clustering of acute paediatric care.

In light of the importance, generally speaking, of carefully considering justification of paediatric examinations resulting in a radiation dose, and CT in particular, it is also viewed as crucial from this perspective to retain medical services at university hospitals and county hospitals for treatment of serious diseases affecting children. In the event of insufficient capacity, it should be possible to request examinations of children from a higher level of hospital care for diagnostics.

The method options of CT, MRI and US

This study demonstrated differences between CT, MRI and US as regards levels of agreement and disagreement on method selection. In terms of US, the level of agreement was very high; for 88% of the examinations, all the reviewers were in agreement on the referring practitioner's choice of US and the US performed. For only 2% of US, the reviewers agreed among themselves that a different method ought to have been chosen. The corresponding outcome for CT was 51% in agreement on CT as the correct method of choice, and for 14% of CT, the reviewers were in agreement on a different preferred method. Consequently, the reviewers taking part in this study were stricter than the reviewers taking part in the 2006 study of CT use in Sweden. At that time, for 8%-9% of the examinations, the reviewers agreed that a different method ought to have been chosen, or that the examination should not have been performed. In this study, the outcome for MRI

ranges between US and CT in terms of agreement on MRI as the correct method of choice, while for only 5% of MRI, the reviewers agreed among themselves on a different preferred method. The share of 5% is comparable to the outcome for the organ areas abdomen and thorax from the 2006 CT study.

When interpreting the difference in outcomes, one should refer in part to the discussion above on the intention of studying routine circumstances in medical care and to the discussion on expected consensus in the profession. We are of the view that the outcomes can be interpreted as follows: The high level of agreement on using US is probably a reflection of a high degree of national consensus on US being an established, frequently used and safe examination method, also that the indications for US are generally well-known and accepted. A contributory factor ought to have been that US is a predominant examination method during infants' first 12 months and also up to the second year of life (ages 0–2). Nevertheless, when separately accounting for the ages 0 to 2 and older than 2 years, the level of agreement is at virtually the same high level as for the older children.

The lack of agreement concerning CT as the correct method of choice and the considerable percentage of disagreement among reviewers is instead assessed to comprise an expression of inadequate national consensus on CT use. Considering the radiation dose received by children, a higher level of agreement would have been valuable. The percentage of examinations for which the reviewers agreed on preferring a different method was at a high level in relation to the outcome of the previous study. This situation is unacceptable, though the total number of CT examinations of children in Sweden is relatively low.

Proposed measures

The profession, in the form of national paediatric societies, should liaise with the Swedish society of paediatric and adolescent radiology and the Swedish society of medical physicists in order to define national guidelines targeting CT use for high-priority organ areas. A special focus is needed on alternative examination options such as MRI, US and X-ray. Key areas are neuro, thorax and abdomen/pelvis, including urinary tract. The focus of guidelines should be on defining the indications where CT cannot be replaced, or where the necessary level of diagnostic accuracy can only be achieved by using CT.

Regional differences

The six medical care regions in Sweden did not differ considerably in terms of justification and quality of referrals. In all the regions, the level of justification and referral quality was high (Figures 12, 14).

The largest number of examinations per million children was performed in the Stockholm-Gotland region, followed by the North region (Figure 7).

In the Stockholm-Gotland region, significantly more US examinations were performed per million children than compared with the other regions, where use of ultrasound did not differ substantially (Figure 9). A similar high level of agreement in terms of choosing US was observed on the part of all regions in Sweden.

The largest number of CT referrals per million children was represented by the North region, followed by the West region. In addition, the North and West regions were the only regions in which a greater number of CT examinations were performed than MRI examinations. A larger number of MRI examinations were performed than CT examinations in the Southeast (greatest difference), followed by the South and Stockholm-Gotland regions. In the Uppsala-Örebro region, almost the same number of CT and MRI examinations were performed; also, the lowest number of CT and MRI examinations per million children were performed in the Uppsala-Örebro region (Figure 9).

There were differences between regions in terms of the level of agreement when choosing CT and MRI. The West region differed the most as the reviewers agreed among themselves and with the referring practitioner/radiologist, shown as the lowest percentage selecting CT (Figure 18), also with the highest percentage selecting MRI (Figure 20).

It is possible that there is some covariation between regional differences in the number of examinations performed in relation to equipment density per million residents in the regions (Figure 8). The West region had, per million residents, the highest quantity of CT equipment and nearly the lowest quantity of MRI equipment (Table 31).

Proposed measures

More effective and harmonised use of diagnostic imaging can only be achieved by means of carefully considered, thorough and continually updated guidelines that have been prepared and defined by the profession, and that are well established and accepted, preferably on a national level and not only on a regional level.

The choice between CT, MRI, US and X-ray is of importance. For CT in particular, involving a relatively high radiation dose (brain, base of the skull, neck, thorax, abdomen including urinary tract, pelvis, chest, lumbar region, multitrauma), very detailed guidelines for alternative method options should be developed. Provided that these do exist, and

are complied with by all the medical care regions, then the requirements imposed by SSM's regulations are met in practice. An additional perspective is that guidelines of this kind would address regional imbalances as to the availability of examinations using certain methods, particularly as regards low availability of MRI.

CT of children: frequency

The number of CT examinations of children up to age 15 in this study was 651. On a yearly basis, the number of examinations can total around 17,000 and be estimated at 1 examination per 100 children and year. In the United States, an estimated 5 to 9 million CT examinations are performed on *children* (Society of Pediatric Radiology, USA) (4); consequently, an estimated 10 per 100 children in the USA are examined annually using CT. In the Stockholm region, in comparison, 10 CT examinations are performed per 100 residents and year estimated across *the entire* population (source of statistics: specialist adviser in radiology, Stockholm County Council) (3).

The most frequent organ areas for CT examinations are brain/skull, kidneys/urinary tract and abdomen/pelvis. In Sweden, the brain is examined in the neonatal period mainly using US; this is also the case for kidneys/urinary tract and abdomen/pelvis. For instance, for suspected appendicitis in Sweden, paediatric examinations are mainly performed using US, whereas medical services in the United States frequently recommend CT; this is also the case for traumas.

Proposed measures

Measures to limit paediatric CT use coincide with measures to harmonise CT use and reduce differences on regional levels and care levels, etc. Only detailed guidelines defined and developed by the profession for justification and method selection in connection with clinical questions can contribute to optimised CT use while at the same time promoting alternative options that do not result in a radiation dose where this is feasible.

The alternative method options that do not result in a radiation dose must be available with a brief waiting time in order to (for example) avoid having to consider the benefit of a brief waiting time for CT plus simultaneous risk of a radiation dose in relation to an increased level of risk from having an extended waiting time for MRI. This will clearly define the responsibility of the care provider and requester of care to make resources available for safe, consistent and optimal care.

For CT examinations performed after carefully considering the method options, software for dose reduction can lower doses by approx. 15% for certain age groups (16).

When detailed guidelines have become established, it is important to comply with them and thus make them generally recognised and accepted. Compliance with guidelines is checked in the form of audits. The ambition should be to achieve a high level of agreement (consensus) in the profession in assessments of justification and method selection.

In the event that inadequate compliance identified during an audit proves to be attributable to a lack of resources and/or limits in the free choice of patients, an injunction may be needed to give requesters of care and care providers the possibility to rectify identified deficiencies.

A precondition for optimisation of diagnostic imaging on an individual basis is the referrals between departments of health and medical services, including referrals for diagnostic imaging, maintaining a high level of quality. Clinics and practitioners requesting diagnostic imaging examinations need to be aware of the importance of writing referrals that have a high level of quality. They must clearly indicate not only justification on quality level 3 or 4 (14), but also provide information facilitating selection from guideline-based method options.

Ultimately, as in the present report, studies of use of medical services (medical audits) on a national level can be conducted at regular intervals for the purpose of checking the degree of conformity.

9. References

1. SSM Report 2009:03, National Survey on Justification of CT-examinations in Sweden, 2009:03. ISSN: 2000-0456.

2. SSM Report 2010:14, *Patientdoser från röntgenundersökningar i Sverige - utveckling från 2005 till 2008* [Patient doses from medical exposures in Sweden: developments between 2005 and 2008].

3. Source: Stockholm County Council, 2012; specialist adviser in radiology at Stockholm County Council (SLL).

4. Society of Pediatric Radiology – statement.

5. Brenner DJ, Elliston CD, Hall EJ, Berdon WE: Estimated Risks of Radiation-Induced Fatal Cancer from Pediatric CT. AJR 2001; 176:289-296. 0361-803X/01/1762-289.

6. Bernier MO, Rehel JL, Brisse HJ et al.: Radiation exposure from CT in early childhood: a French large-scale multicentre study. BJR. 2012; 85: 53-68.

7. Pearce MS, Salotti J A, Little MP, McHush K, Lee C, Kim KP, Howe NL, Ronckers CM, Rafaraman P, Craft AW, Parker L, de González AB. Lancet online 7 June 2012. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours; a retrospective cohort study.

8. The Swedish Radiation Safety Authority's regulations (SSMFS 2008:35) on general obligations in medical and dental practices using ionising radiation.

9. EU guidelines: Referral guidelines for imaging: Radiation Protection 118. EU, 2000. http://ec.europa.eu/energy/nuclear/radioprotection/publication/doc/118_en.pdf.

10. *Remitteringsstandard* [Standard for referrals]. Focus report, medical programme project, Stockholm County Council, 2005. Isberg B, Jorulf H.

11. SOSFS 2004:11, the National Board of Health and Welfare's regulations concerning responsibility for patient referrals in areas including health, medical and dental care.

12. SSMFS 2008:20, the Swedish Radiation Safety Authority's regulations and general advice concerning diagnostic standard doses and reference levels in medical imaging diagnostics.

13. SSMFS 2008:31, the Swedish Radiation Safety Authority's regulations concerning imaging diagnostics.

14. Fryback DG, Thornbury JR: The efficacy of diagnostic imaging. Med Decis Making. 1991 Apr-Jun; 11(2):88-94.

15. *Kartläggning av Magnetisk Resonanstomografi (MRT) i Stockholms län 2004 – bedömning av remisskvalitet och berättigande* [General survey of magnetic resonance imaging (MRI) in Stockholm County, 2004: assessing referral quality and justification]. Comparison with the 2001 report. Focus report, medical programme project, Stockholm County Council, 2006.

16. Ledenius K: Optimization of Paediatric CT Examinations. University of Gothenburg, Thesis 2011, ISBN 978-91-628-8223-5.

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The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 300 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

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