

Can pediatric radiography be practiced appropriately in a hospital, without a dedicated diagnostic imaging unit? A case study.

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Abstract

Introduction

Due to Norway's population density, demographic scatter and topography, performing radiological examinations in children in the same unit as in adults is quite common despite international guidelines recommending use of dedicated pediatric radiology units. Children examined in non-dedicated pediatric facilities are therefore a unique patient group who requires special attention.

This study investigates pediatric radiography practice at a small local hospital lacking a dedicated pediatric radiology department by comparing it with the ideals of good practice as stated by international agencies. The aspects analyzed are organization, radiation safety and optimization.

Methods

The approach is qualitative, based on participant observation, document investigation and interviews with radiographers.

Results

Radiologists evaluated referrals. Age specific pediatric CT-protocols were being used. Awareness of the greater radiation risk in children and radiation safety concern were common among the radiographers. Some radiographers had experience from pediatric

imaging departments while none of them had postgraduate studies in pediatric radiography. Lack of extensive practice due to reduced pediatric patient volume makes sometimes the examination of children be a challenging task. Communication with children seemed to go well.

Conclusion

Despite variations in experience with children among radiographers and lack of specialization in pediatric radiography, the practice is largely in accordance with international recommendations. Radiation protection and optimization requirements met, although the departmental organization slightly diverges from prevailing guidelines. Slightly different practice and experience with children among radiographers indicate the need for special guidelines for pediatric imaging for non-dedicated pediatric radiology departments.

Introduction

Pediatric patients require different handling than adults due to higher risk of radiation-induced cancer and lower understanding and communication ability comparing to adults (1). A successful pediatric radiology examination requires in-depth knowledge of children's developmental and functional level and ability to establish a safe atmosphere in the examination situation. Without such expertise, X-ray and CT examinations, are often repeated; due to motion artifacts. International guidelines (2, 3, 4) recommend therefore that radiological examinations of Children should receive treatment in dedicated pediatric radiology units. Norway's lower population density, demographic distribution and unique topography presents unique challenges for the medical system. One of them is the quite common practice that radiological examinations in children sometimes are performed at small local hospitals which do not have dedicated pediatric radiology units (1). This practice is not uncommon in other countries either. In USA pediatric trauma patients are usually transferred to hospitals with a pediatric department while 10% of hospitals without pediatric intensive care treat those patients locally (5). Other sources indicate that the majority of children are being investigated with CT on non-pediatric units and that the use of CT in children has increased significantly (6, 7)

The aim of this study was to investigate how pediatric radiography is practiced in a small local hospital that does not have a dedicated pediatric radiology department and where children represent only a small part of the patient volume. The practice was measured against the ideals of good practice in pediatric radiology provided by international agencies (2, 3, 4). The aspects of the practice analyzed in this study are organization, radiation safety and optimization.

To our knowledge, there is a lack of literature on how pediatric radiography is practiced outside the dedicated pediatric radiology departments. Studies on radiological

examinations in children outside pediatric departments do not investigate the radiography practice as a process but rather focus on results by comparing non-dedicated pediatric departments with pediatric radiology departments in terms of radiation doses (8, 9) or number of examinations (6, 7), while other discuss justification of specific CT examination for children (10, 11).

The ideal practice according to guidelines

Organization

An ideal framework should reduce radiation dose to the minimum necessary to maintain diagnostic image quality and minimize stress for children, parents and employees (2).

International Atomic Energy Association (IAEA) (2) recommends dedicated pediatric rooms or times dedicated to pediatric radiology so that children and adults are not waiting in the same queue. Additionally both waiting rooms as well as examination rooms should be child-friendly.

IAEA emphasizes the importance of communication to achieve the child's trust and cooperation and reduce the chances of unsuccessful investigations that impose unnecessary radiation on the patient. When scheduling the examinations, one should consider that children require approx. 50% more time than adults for most examinations. (2)

Communication with the patient and parents begins with the appointment letter, which should contain a brief and clear description of the examination and any eventual preparation. Brochures containing photos of children undergoing the examination can be informative for parents and relaxing for children. (2)

It is recommended to take time to show the child the CT scanner, familiarize the patient to the table motion and practice the breathing instructions in advance. If an intravenous intravenous route of administration line is required, it should be installed in advance of the examination (3).

For small children it is recommended that parents are present in the room during the entire examination. (2, 3, 4).

According to recommendations (2, 4) examinations of children should be performed by experienced staff specialized in pediatric radiography.

Radiation protection

Radiological examinations in children carry a higher risk, on average, for the development of cancer per radiation dose unit compared to adults (12). The patient's lower age gives more time for harmful effects of radiation to manifest, and organs and tissues under development are more sensitive to radiation (4).

Radiation protection measures are extremely important in the case of CT because the radiation doses are much higher compared to conventional x-ray and the use of CT is increasing (12). The International Commission on Radiological Protection (ICRP) (4) estimates that 7-10% of the CT studies are performed in children and IAEA (2) refers to studies that estimate that between one third and half of the CT examinations carried out on children have dubious indications. Justification requires that chosen method of investigation is necessary and reliable, i.e. it has sufficient sensitivity, specificity, accuracy, and answers to the clinical question; and that techniques that do not use ionizing radiation, such as ultrasound and MRI should always be considered as an alternative imaging modality (4).

The following are examples of X-ray examinations that, according to ICRP (4), are not justified in children:

- head in children with epilepsy or headache
- sinuses in children under 6 years of age
- cervical spine in children with torticollis without trauma
- opposite side for comparison in case of injury
- scaphoid in children under 6 years of age
- X-ray thorax for acute pulmonary infections prior to treatment start
- CT for minor head injury (estimated incidence of injury requiring neurosurgery is as low as 0.02 %.) or injury with no loss of consciousness or consciousness loss for shorter than 5 seconds, no scalp hematoma except frontal, no vomiting, and no serious headache (3).

Skeletal or spine CT scans are not recommended as the first examination for trauma, but only as an additional method in doubt after performing conventional X-ray examination (3).

Another recommendation is the selective use of thorax CT in blunt trauma which in most cases is not worth the radiation risk as it doesn't change the patient management (10) and abdominopelvic CT imaging that includes the lower chest might eliminate the need for thorax CT as significant intrathoracic injuries requiring intervention occur most often in the lower chest (11).

An important radiation protection rule is trying to avoid image retake. Patient positioning and collimation must be accurate even if the patient does not cooperate in order to achieve proper projection and avoid irradiating a larger area than necessary (4). Therefore, immobilization of infants and young children may be necessary. It is recommended that the parents hold the child because that both calms the patient and avoid additional radiation exposure of employees who are already subjected to potential occupational exposure (2, 4). The parents should wear protective equipment and stay outside the primary beam field. If immobilization equipment is used it should be easy to use and the application should not be

traumatic to the patient and the benefits of immobilization should be explained to the parents (4). In order to reduce the child's discomfort during immobilization the examination should be performed quickly, and everything should be prepared in advance (i.e. exposure parameter settings).

Use of lead shielding is recommended when radiation sensitive organs lie within the primary X-ray field or within 5 cm from it, and the stated achievable dose reduction is 30-40% by shielding with 0.25 mm lead equivalent material at 60-80 kV (4). In CT, bismuth protection is recommended to protect sensitive organs from direct or scattered radiation but only if the diagnostic value of the study is not affected, and an estimated reduction of absorbed dose is 50-70% (4). Inadequately positioned shielding can produce artifacts and increased noise. It should also be considered that if protective equipment is not used properly, it can actually increase the radiation dose (e.g. by placing it before the scout when using tube current modulation).

Optimization

In Norway it is required by law that all radiation usage should be justified and optimized (13).

The fundamental goal of optimization is to adjust radiation exposure and introduce safety measures in such a way that the required image quality is achieved with the lowest possible radiation dose, i.e. ALARA (as low as reasonable achievable) principle must be followed for each examination.

Suggested optimization measures are adaptation of exposure parameters, use of adjusted positioning (such as posteroanterior projection instead of anteroposterior in imaging of thoracic spine in pubertal female patients to reduce breast tissue exposure) avoidance of the use of anti-scatter grids when possible (4).

Special considerations for dose-reducing functions when purchasing new machines (such as tubes with the ability to add extra filtration or bucky with removable grids) are regarded as part of the optimization process (2, 4). However, procedures for using dose-reducing techniques are considered more important than having pediatric dedicated X-ray equipment (14).

Increased radiation doses for pediatric examinations in non-pediatric departments compared to pediatric departments were found (7, 8). However, it is claimed that non-pediatric units can achieve the same dose levels as pediatric units (5). Radiologists' attitude towards image quality is crucial. A distinction should be made between diagnostic quality and aesthetic quality, and higher image noise should be accepted to reduce radiation dose if the image quality is sufficient for diagnostic (3).

Methods

The study has a qualitative approach with a phenomenological methodological orientation. Methods used are observation, document investigations and interviews with radiographers.

Observation was used in addition to interview in order to provide direct access to situations unadulterated by participants' interpretations. Observation took place over three weeks by the first author's personal participation in the department's activity. All the procedures related to pediatric patients among the documents available on the institution's intranet, the CT protocols available on paper in the CT operator room, information posters on the walls and notes from departmental meetings were investigated.

We chose to conduct the observation before the interviews in order to avoid the influence that reflecting on pediatric radiography issues might have on the radiographer's behavior. The awareness of being observed might have altered the radiographers' behavior (Hawthorne effect); we tried to reduce this effect by using continuous observation over three weeks to let the radiographers get used to the presence of the observer. Instead of using an interview guide there was used a list containing the main topics that the participants were invited to talk freely about in order to avoid missing aspects that the authors didn't think of. Both individual interviews and group conversations were used. All the five radiographers participated. The interviews were not recorded on tape, only written notes were taken. The use of hand-written notes instead of recording during the interview increased the informants' comfortability. The interview notes were juxtaposed against field-notes in order to enhance the validity of the analyses.

All participants were informed about the purpose of the study and have expressed their participation consent. They have read the article draft (in Norwegian) and consented to publication. It was agreed that the hospital's name will not be made public out of consideration to the anonymity of participants and the possibility to touch on vulnerable internal aspects.

Results and discussion

Organization

The hospital is a small local hospital that serves three municipalities and has emergency function. The department has conventional X-ray, CT, fluoroscopy and ultrasound and is staffed by five radiographers, a radiologist and office staff. For scheduled examinations, children are usually referred to the pediatric radiology department at the regional hospital. Driving time to the nearest regional hospital is approx. 2.5 hours and this sometimes comes in addition to up to 1.5 hours' drive from home to the local hospital. The children who undergo radiological examinations at the department are mainly emergency patients, most

of the cases are injuries investigated and treated at the orthopedic department. The only planned pediatric imaging procedures are conducted on patients who were previously treated for orthopedic injury at the hospital and receive an invitation for follow up that includes new radiologic examination. CT examinations are rarely performed in children, the most common examination is head and neck CT of trauma patients, and more rarely, thoracoabdominal CT to rule out injury of the internal organs.

Although there are no dedicated pediatric examination rooms or waiting areas as recommended, the rooms are child-friendly with a little play area in the waiting room. In the examination room there is a big teddy bear and a box of small toys from which the patient may choose a gift after the examination. The children also get humorous stickers that say they were good at X-rays.

The recommendations to reduce waiting time for pediatric patients as much as possible are followed by prioritizing them in the queue. It appears that communication with the children works well in most cases. According to the radiographers, essential elements in communicating with children are to divert the child, be honest (do not say that it does not hurt when you place a venous line) spend more time, explain in detail, take care of being at the same height as the patient. It was observed that radiographers also practice what they recommend. As a rule, they take the time they need to chat with children and parents, with some exceptions during the shifts with many trauma patients. The children are distracted with small talk and toys, one of the radiographers usually tells the patient that the LED on the detector will blink when "taking the picture". Most radiographers inform the patient about the noise made by the CT scanner. The recommendations (2) on early placing of intravenous line and showing how the CT scanner works are most commonly followed, except for severe emergency cases, but these patients are already medicated from the surveillance room. In case of scheduled CT examinations, the radiographer shows the patient the CT machine, some radiographers place a large teddy bear on the table and drive it in and out of the gantry. The children who need contrast agent administration are usually trauma patients who already have a venous line when they arrive.

Parents are staying in the room with small children, as recommended by guidelines. There was consensus among all respondents that presence of parents in the room when investigating older children requests an individual assessment. A mentioned challenge was asking teenagers about pregnancy in the presence of their parents. Another challenge was very young trauma patients who get scared when they see the entire trauma team in the room. One of the radiographers expressed preoccupation to check the story that is being told about the injury mechanism out of concern of child abuse.

There is no special template for appointment letters adapted to children or child-friendly information brochures as guidelines recommend (1, 2) but children examined at the department are either emergency patients or orthopedic patients called in for follow-up and

they are already familiar with the X-ray equipment and procedures from their previous examination.

Some of the radiographers have experience from previous positions at pediatric departments while none of them has formal specialization in child radiography as recommended by all instances (1,2,3), but it would be an unreasonable requirement for an imaging department with only five radiographers where most of the patients are adults. The department doesn't prioritize the employees' specialization in pediatric radiography due to reduced pediatric patient volume, financial reasons along with insufficient number of radiographers who can cover the shifts in the absence of the person who is taking a course. Three out of five radiographers at the department have postgraduate education in CT and one has postgraduate education in radiation protection. Some of the radiographers expressed that sometimes examinations of children can be challenging. The challenge that appeared frequently in the conversations is that there are not enough patients for them to "train" and improve in pediatric radiography.

Radiation protection

All pediatric referrals are assessed by a radiologist regarding justification and optimal choice of modality and projections in concordance with the guidelines (2, 3).

Replacement of required examination with non-irradiating alternative techniques as ultrasound and MRI is often considered but the department does not have MRI, and this can be considered an inconvenient for an imaging department that examines children, although children are only a small part of the patient volume. Thus, when a quick clarification of findings on conventional radiograph is necessary to get started with treatment as soon as possible, CT is used even though MRI would have been a better choice. However, this is rather an exception, most of the pediatric patients with unclear findings are referred to MRI at the pediatric radiology department at the regional hospital.

Some investigations from the list (3) with unjustified examinations (opposite side for comparison, CT for minor head injury without consciousness loss) are sometimes performed and CT is sometimes used as first choice in spine or thorax trauma contrary to the recommendations (2, 9, 10).

All the radiographers in the study were aware of an increased risk of radiation harm in children and eager to protect the patients from radiation. Therefore, lead shielding might be used more often than necessary, as for example in examination of extremities, even though protection is recommended only when sensitive organs are within 5 cm of the primary radiation field (3). Bismuth shields are used in CT in accordance with the guidelines (3), with very few exceptions in critical trauma patients when the use of eye lens protection equipment is forgotten in the inevitable rush.

The department has no immobilization equipment as recommended (2, 3) but it is neither necessary since they never perform X-ray examinations on infants, and children can be held by the parents if necessary. Parents are provided lead aprons and are told to stay outside the primary beam field, they are also informed about the importance of immobilization in line with international recommendations (4).

Optimization

As all instances (2, 3, 4) recommend, dedicated pediatric CT protocols are always used. Instruction list placed on the wall in the operator room states that pediatric CT protocols should always be used in children with a body weight under 45 kg and includes tables for adjusting exposure parameters to the patient's size. However, some radiographers use the standard pediatric CT protocol without any adjustments.

On conventional X-ray examinations, automatic exposure control function is used when appropriate, the exposure is automatically adjustable to different patient sizes and this is consistent with the recommendations. In some cases, manually adjusting of exposure parameters is also used to fine-tune the exposure.

Improvisation is used when positioning the patient in order to reduce the child's pain or discomfort, but alternative dose-reducing positioning variants, such as posteroanterior instead of anteroposterior when imaging thoracic spine (4), are seldom used. Anti-scatter grids are almost never used in pediatric examinations and this complies with the recommendations (4).

All periodic quality controls are regularly performed and documented as recommended. The X-ray equipment has removable anti-scatter grid, which is the minimal requirement of dose reduction functions for pediatric use (2, 4), but it is not possible to add extra filters to the X-ray tube.

The recommendations of use of dedicated pediatric X-ray equipment in children (1, 2, 3) are obviously not fulfilled as an inevitable consequence of the department's low pediatric patient volume. However, the standards have a rather informative purpose and the procedures for using low dose techniques are considered more important than having dedicated pediatric X-ray equipment (14) given that non-pediatric departments can achieve the same dose reduction in children as pediatric departments (6).

Most radiologists follow the recommendations (4) to place greater emphasis on dose reduction in children than on aesthetic image quality and accept higher image noise if the images have sufficient diagnostic value. In general, more noise is accepted in CT examinations of children than in adults.

There seems to be great interest in optimization and dose reduction for children in the department. Challenging pediatric cases are often discussed during the breaks; if things

remain unclear or if unusual situations require assessment of procedures, this is discussed at the weekly departmental meeting where the radiologist is also present.

Conclusion

In regions with low population density it is not reasonable to expect that all examinations in children are performed in dedicated pediatric radiology departments, although most instances (2, 3, 4) recommend this. Pediatric patients examined on non-dedicated pediatric imaging units are therefore a user group with a unique need for adaptation of practice procedures.

A departmental organization which slightly diverges from prevailing guidelines is not an impediment to meeting the radiation protection and optimization requirements. Despite variations in experience with children among the radiographers and no specialization or training in pediatric radiography, the practice is largely in accordance with international recommendations.

It seems like postgraduate education in radiation protection and CT (which also places great emphasis on radiation protection of children) can compensate for lack of specialization in pediatric radiography. Since small departments where children represent only a small part of the patient volume cannot prioritize further education in pediatric radiography, development of online courses might be a beneficial measure. Another solution is the establishment of special guidelines for pediatric radiography practice outside pediatric departments like in Australia, where examinations of children in non-dedicated pediatric radiology departments occur quite often due to similar geographical conditions (15).

Since in small hospitals it cannot be required that all radiographers should have special expertise or experience in pediatric radiography. However, the major limitation of the study is that the findings are based on data from only one department and therefore have very limited generalization value.

Further research on the practice at other hospitals is needed in order to investigate how pediatric radiography practice in non-dedicated imaging departments can be improved, and what measures can help the radiographers in these departments with possible challenges related to pediatric patients.

It would also be interesting to investigate whether there are differences in pediatric patient doses between pediatric and non-pediatric radiology departments as showed in literature (8, 9) and between different non-pediatric hospitals.

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