Received:
14 August 2013

Revised:
10 December 2013

Accepted:
17 December 2013

doi: 10.1259/bjr.20130517

Cite this article as:
Goske MJ. Doctor, is a CT scan safe for my child?. Br J Radiol 2014;87:20130517.

COMMENTARY

Doctor, is a CT scan safe for my child?

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Medical professionals and international organizations have promoted radiation protection for patients since the early 1900s when organizations such as the British Roentgen Society and American Roentgen Ray Society were founded.¹ However, it was the 2007 article by Brenner and Hall² and the release of such publications as the National Council on Radiation Protection and Measurement's Report 160 that prompted the much needed public debate in the media and by the public on increasing radiation exposure from CT scans.^{3,4} Within the past 15 months, three large epidemiological studies, including the most recent one by Miglioretti et al,⁵ have assessed the risk of cancer due to CT imaging in children.^{6,7} The purpose of this commentary is to consider whether the Miglioretti article and the other two research studies on radiation protection in children should impact parents' perception of CT safety for their child. Do these articles help answer a parent's most common and difficult question, "Doctor, is a CT scan safe for my child?"

The Miglioretti study had 3 main findings: estimates of the rates of CT scan use in children younger than 15 years from a population comprising 4 857 736 child-years; estimates of organ and effective doses using a credible new measure based on sex- and age-specific computational anatomic phantoms in a subpopulation of 744 randomly selected CT scans; and assessment of the projected excess lifetime cancer risk attributed to CT scans in this population.⁵

FINDING 1: ESTIMATES OF THE RATES OF CT USE

Estimates of rates of CT use were relatively straightforward in the Miglioretti article.⁵ Rates of CT scans from 1995 to 2005 increased at a significant rate, plateaued in 2006 and 2007 and then declined. These findings mirror several other studies on CT use in the paediatric population and are not controversial within the radiology community.^{8,9} The other two articles^{6,7} provided data on the number of CT scans within the study time frames, but did not assess utilization. CT use at a national level is not likely to be central to a parent's interest, as they are interested in *their* child's need for a CT scan and not focused on population statistics.

FINDING 2: ESTIMATES OF EFFECTIVE RADIATION DOSE

Pearce et al⁶ estimated radiation dose based on typical CT scanner settings for young people from 1989 and 2003 to estimate absorbed dose for "reference patients" and did not obtain actual patient dose data. In the Australian study by Mathews et al,⁷ the primary outcome measure was cancer incidence; the study did not address radiation dose per CT scan directly. In the Miglioretti article, estimates of the number of patients with an effective dose >20 mSv were higher than the estimates for paediatric CT in the past. Because parents want their child to receive the minimal necessary radiation dose, they will sometimes ask "Did the CT scan my child received use a 'child-sized' dose of radiation?"¹⁰ The data from this article tell us that the answer may be "no". Parents should be very interested in this finding because it implies that their child may receive a higher radiation dose than is warranted for the necessary examination.

In addition, the Miglioretti article highlighted significant variation of CT dose among facilities. Because CT dose varied so much between sites for the same examination, between 3% and 25% (depending on the anatomic location), some patients received a larger dose of radiation than they could have received if scanned at another institution. In that regard, the Miglioretti article is noteworthy for both parents and radiologists. Parents, particularly parents with children who have chronic illness, may choose to use this information to investigate CT doses at a specific facility and choose to take their child to a facility with lower doses. Radiologists in countries with relevant statutory requirements will have their patient dose data and should be able to compare their internal data with those of reference institutions or national data. Other radiologists (in countries where there is no legal control on the amount of radiation that a patient may receive) may not. For those radiologists, it may be difficult to answer a parent's question. Blanket assurances to parents that "the lowest dose was used" may be wrong and are inappropriate. This underscores the need for facilities throughout the world to have teams of individuals responsible for patient care in CT as part of a robust quality assurance programme, as is required by law in many

countries throughout the world.¹¹ The medical imaging team shares the responsibility to ensure radiation protection for children under their care. Justification for each paediatric CT scan and the judicious use and rigorous monitoring of patient dose need to occur irrespective of whether it is required by law. Members of the team include the radiologist, medical imaging physicist, radiographer and CT manufacturer.¹⁰ Medical imaging professionals (and that includes referring physicians) who are part of the patient care team should attend training updates on an ongoing basis to learn newer concepts related to radiation biology, risk, risk communication, dose optimization and other relevant aspects of paediatric patient radiation protection.

There is a significant gap in knowledge that is relevant to estimating paediatric radiation doses. While the Miglioretti report provided organ and effective doses from their study group, there are few studies that address what the organ or effective dose *should* be for a CT scan based on anatomic part scanned, patient size and clinical indication. The first attempt to fill this gap in paediatric patients was made in 1999 in the UK through the development of diagnostic reference levels for paediatric CT.¹² Since that time, only a handful of countries have published paediatric diagnostic reference levels for CT to provide target values so that one facility can compare their practice with other similar practices. More recently, the development of diagnostic reference ranges that take into account image quality are being developed for children in the USA.¹³ As further research addresses this gap in knowledge, the question of a “child-sized” CT dose may be easier to answer for parents. Increasing use of registries with automatic upload of data such as that developed by the American College of Radiology will aid in providing benchmarks to be used as guidance locally.

FINDING 3: ESTIMATES OF LIFETIME CANCER RISK

All three articles project the lifetime attributable risk of cancer. The articles agree that the younger the patient and the higher the radiation dose for each CT scan, the greater the risk of excess cancer. This information might help inform parents generally but is not specific enough. The most consistent and most challenging question raised by parents is whether or not a CT scan will cause cancer in *their* child. Parental understanding of ionizing radiation and its use in medical imaging is generally minimal. Parents cannot see radiation, and the possible stochastic effects may take years to occur. Until the recent development of size-specific dose estimates, rapid estimates of individual patient dose after a CT scan were not available.¹⁴ Finally, the potential excess risk of cancer is incremental to the baseline risk of cancer. It is estimated that more than one in three people will be diagnosed with some form of cancer during their lifetime.¹⁵ It is unrealistic to expect parents to understand population statistics, laws of chance and probability, or the concept of causation. Furthermore, probability of causation (*e.g.* one in so many will get cancer) is not useful in any practical sense for estimating an individual's cancer risk because the data are derived from population averages and cannot be accurately applied to an individual. The population data do not account for individual differences owing to environmental risk factors or individual biological factors. By definition, the excess cancer risk is not a true individual risk but a risk shared by the total population.

The risk discussion is further clouded by heuristics, where a parent may simplify the risk, that is, CT is “good” or CT is “bad”. A simple definition of heuristics is that it represents the set of shortcuts people use to solve problems and make judgements rapidly and efficiently; such shortcuts may be prone to systematic errors or bias. There is a considerable body of work within the field of cognitive psychology that indicates that a discussion of risk may lead to bias in how parents would interpret information and potentially refuse indicated examinations.^{16,17} It is no wonder that parents and some physicians are confused.

The Miglioretti article does not provide information on the potential benefits that a child may have realized by having the CT scan performed. Although that was beyond the scope of the Miglioretti study, discussion of any potential risk without discussion of the corresponding benefit is not useful. For instance, if one is buying a car and the only discussion relates to the risk of death over one's lifetime from a motor vehicle accident (1 in 304) and not the practical benefit of car travel (getting to work or reaching a vacation destination), then the discussion of risk related to car travel is meaningless.¹⁸

So where does that leave parents and radiologists in the discussion of risk? Parents need to know about the risk of CT scans and the benefits, prior to the study, to make an informed decision. The parent also needs to know what would happen if no CT is done, and whether there are other strategies that can answer the medical questions. Some argue for a formal process of informed consent prior to CT scans, whereas others feel this would be onerous and inappropriate given the extremely low risk. One thing seems clear—parents have the right to be informed about the risks and benefits of a test involving ionizing radiation, and they have the right to this information *before* the test. As opposed to “informed consent”, which some view as a unidirectional and legalistic disclosure of alternatives, risks and benefits by the physician, “informed decision making” may be an alternative by providing a “meaningful dialogue between physicians and patient”.¹⁹ Parents who have not received information about risk from ionizing radiation may feel deceived by the medical profession, to whom they entrusted their child. They need to know that the CT scan is necessary, that there is a potential risk, that the risk for imaging tests is low and that the minimal necessary dose of radiation is used. Mostly, they want to understand why the scan is being performed and how it will help physicians care for their child. In this regard, the specific risk factors provided by Miglioretti, taken alone, are of minimal use to parents.

Does that mean that studies such as the one by Miglioretti are not important in furthering our understanding of potential effects from CT? The answer is “no”. Their risk estimates, however accurate, however controversial, keep a focus on the need to justify *every* paediatric CT, to “child-size” the CT dose for paediatric patients and to closely monitor and compare results with other similar sites. The study also implies the need for continued refinement of diagnostic reference levels and, most importantly, communication with parents. For those countries where the concept of justification, optimization, diagnostic reference levels and quality improvement are gaining traction, we *can* learn from countries where these principles have been inherent to the definition of radiation protection since its inception.¹¹ As Picano²⁰

states, “better knowledge of risks will help us avoid small individual risks translating into substantial population risks”. So, when a parent asks the question “Doctor, is a CT scan safe for my child?”, we should be able to look the parent in the eyes and let them know that we have worked to ensure that their child’s CT scan is necessary and that the scan is as safe as possible. Parents, on behalf of their children, will be positioned to make informed

decisions when provided with information about the potential benefits and risks of the scan and, in most cases, the considerable magnitude of the benefits relative to the risks. It is time to add these discussions to the routine practice of paediatric radiology, so that maximum benefit can occur with the least risk. This approach is necessary to responsibly leverage the power of CT for accuracy and precision in medical diagnosis.

REFERENCES

- Kathern RL, Ziemer PL. The first fifty years of radiation protection—a brief sketch. In: Kathern R, Ziemer P, eds. *Health physics: a backward glance*. Oxford, UK: Pergamon Press; 1980 [cited 18 November 2013]. The Health Physics Society. Available from: <http://www.umich.edu/~radinfo/introduction/50yrs.htm#top>
- Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. *N Engl J Med* 2007; **357**: 2277–84.
- National Council on Radiation Protection and Measurements. *Ionizing radiation exposure of the population of the United States 2009*. NCRP report no. 160. Bethesda, MD: National Council on Radiation Protection and Measurements; 2009. doi: 10.1021/ac902650w
- Sternberg S. Study: unnecessary CT scans exposing patients to excessive radiation. *USA Today*. November 2007 [updated 29 November 2007; cited 18 November 2013]. Available from: http://usatoday30.usatoday.com/news/health/2007-11-28-dangerous-scans_N.htm
- Miglioretti D, Johnson E, Williams A, Greenlee RT, Weinmann S, Solberg L, et al. The use of computed tomography in pediatrics and the associated radiation exposure and estimated risk of cancer. *JAMA Pediatr* 2013; **167**: 700–7. doi: 10.1001/jamapediatrics.2013.311
- Pearce MS, Salotti HA, Little MP, McHugh K, Lee C, Kim KP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumors: a retrospective cohort study. *Lancet* 2012; **380**: 499–505. doi: 10.1016/S0140-6736(12)60815-0
- Mathews JD, Forsythe AV, Brady Z, Butler MW, Goergen SK, Byrnes GB, et al. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. *BMJ* 2013; **167**: 700–7.
- Townsend BA, Callahan MJ, Zurakowski D, Taylor GA. Has pediatric CT at children’s hospitals reached its peak. *AJR Am J Roentgenol* 2010; **194**: 1194–6. doi: 10.2214/AJR.09.3682
- Menoch MJ, Hirsch DA, Khan NS, Simon HK, Sturm JJ. Trends in computed tomography utilization in the pediatric emergency department. *Pediatrics* 2012; **129**: e690–7. doi: 10.1542/peds.2011-2548
- Goske MJ, Applegate KE, Boylan J, Butler PF, Callahan MJ, Coley BD, et al. The image gently campaign: working together to change practice. *AJR Am J Roentgenol* 2008; **190**: 273–4. doi: 10.2214/AJR.07.3526
- European guidelines on quality criteria for computed tomography. European Union Report, EUR16262. Luxembourg: Office for Official Publications of the European Communities; 1999.
- Shrimpton PC, Hillier MC, Lewis MA, Dunn M. Reference doses for paediatric computed tomography. *Radiat Prot Dosimetry* 2000; **90**: 249–52.
- Goske MJ, Strauss KJ, Coombs LP, Mandel KE, Towbin AJ, Larson DB, et al. Diagnostic reference ranges for pediatric abdominal CT. *Radiology* 2013; **268**: 208–18. doi: 10.1148/radiol.13120730
- Boone JM, Strauss KJ, Cody DD, McCollough CH, McNitt-Gray MF, Toth TL. *Size specific dose estimates (SSDE) in pediatric and adult body CT examinations*. College Park, MD: American Association of Physicists in Medicine; 2011 [cited 18 November 2013]. Available from: http://www.aapm.org/pubs/reports/rpt_204.pdf.
- Cancer Research UK [homepage on the internet]. What is the lifetime risk of developing cancer? [updated 26 July 2012; cited 18 November 2013]. Available from: <http://www.cancerresearchuk.org/cancer-info/cancerstats/incidence/risk/>
- Lloyd AJ. The extent of patients’ understanding of the risks of treatments. *Qual Health Care* 2001; **10**(Suppl. 1): i14–8.
- Redelmeier DA, Rozin P, Kahneman D. Understanding patients’ decisions: cognitive and emotional perspectives. *JAMA* 1993; **270**: 72–6.
- Fahey FH, Treves ST, Adelstein SJ. Minimizing and communicating radiation risk in pediatric nuclear medicine. *J Nucl Med* 2011; **52**: 1240–51. doi: 10.2967/jnumed.109.069609
- Brink JA, Goske MJ, Patti JA. Informed decision making trumps informed consent for medical imaging with ionizing radiation. *Radiology* 2012; **262**: 11–14. doi: 10.1148/radiol.11111421
- Picano E. Informed consent and communication risk from radiological and nuclear medicine examinations: how to escape from a communication inferno. *BMJ* 2004; **329**: 849–51. doi: 10.1136/bmj.329.7470.849