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Minimising medically unwarranted computed tomography scans

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Abstract–As computed tomography (CT) is such a superb diagnostic tool and individual CT risks are small, whenever a CT scan is clinically warranted, the CT benefit/risk balance is by far in the patient's favour. However, if a CT scan is not clinically warranted, this balance shifts dramatically. It is likely that at least 25% of CT scans fall into this latter category, in that they could either be replaced with alternative imaging modalities or could be avoided entirely. Use of clinical decision rules for CT usage represents a powerful approach for slowing down the increase in CT usage, because they have the potential to overcome some of the major factors that result in some CT scans being undertaken when they may not be clinically helpful.

Keywords: CT; Clinically unwarranted scans; Decision rules

1. INTRODUCTION

The number of CT scans currently performed annually in the US and Japan are respectively about 85 and 63 million (International Marketing Ventures, 2012; Tsushima et al., 2010). Overall, CT scans are the single most important contributor to the estimated worldwide collective effective dose from diagnostic imaging of approximately 4 million person-Sv/year (UNSCEAR, 2010).

At typical organ doses relevant to most CT usage [5–100 mSv (Hall and Brenner, 2008)], the x-ray exposure represents a very small but well-established individual cancer risk (Brenner et al., 2007; Pearce et al., 2012), particularly for patients without significantly reduced life expectancy (Brenner et al., 2011). It follows from this,

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and because CT is such a superb diagnostic tool, that when a CT scan is clinically warranted, the CT benefit/risk balance is by far in the patient's favour. The issue here is the collective dose and the population risk produced by clinically unwarranted CT scans, and thus the goal is to minimise the number of such scans (Hricak et al., 2011).

2. CT USAGE

While CT usage is most common in Japan and the USA, the rates of increase in usage are fairly similar in many other countries (Mettler et al., 2008, 2009; Brady et al., 2011; Pearce et al., 2011). For example, the annual rate of increase in CT usage over the last decade is 6.5% in the US and 9.4% in the UK (International Marketing Ventures, 2012; Department of Health, 2012). The current usage is estimated to be more than 3 million per year in the UK, and approximately 80 million per year in the USA. In the USA, 5–10% of all CT scans are performed on children (Mettler et al., 2000; Stern et al., 2001).

The various CT-based health screening applications (lung cancer screening, CT colonography, cardiac screening) are probably not quite ready for mass use, but some may be soon, which is expected to result in an further jump in CT usage (Furtado et al., 2005; Waugh et al., 2006; Black, 2007; Pickhardt and Kim, 2007; Hall and Brenner, 2008; Rockey, 2010; Aberle et al., 2011).

2.1. Multiple CT scans

While the mean number of CT scans delivered in the USA is approximately 80 million, the number of individuals involved is likely to be closer to 30 million, as individuals who have one CT scan for a particular medical issue have, on average, between two and three CT scans (Mettler et al., 2000; Winslow et al., 2008).

In terms of the number of CT scans that people receive in the long term, Sodickson et al. (2009) surveyed 31,000 individuals who had CT scans in 2007, and traced the number of CT scans each had received in the previous 20 years. The average number of CT scans was six, with 1% of the individuals receiving at least 38 CT scans. The maximum number of CT scans was 132.

Another issue here is the number of 'double CT' scans performed (i.e. both with and without contrast material) (Patz et al., 1999). In the USA, for example, approximately 5% of all chest CT scans are performed both with and without contrast enhancement (DHHS, 2012), effectively doubling the dose without any concomitant increase in the information accrued (McHugh and Disini, 2011).

3. POTENTIAL RISKS ASSOCIATED WITH CT SCANS

Concerns arise because a CT scan results in organ doses that are very much larger than those from conventional radiological procedures such as chest x rays. The typical maximum organ dose for a set (one or more) of CT scans for a given ailment ranges from approximately 5 to 100 mSv (Hall and Brenner, 2008); this wide dose range is due to variability in the number of scans, the type of scans, machine and machine-setting variability, and age/size variability (Stern et al., 2001; Hall and Brenner, 2008). There is now direct epidemiological evidence of small but statistically significant cancer risks associated with the radiation from CT scans (Pearce et al., 2012). In addition, in this dose range (5–100 mSv), there is epidemiological evidence (Pierce and Preston, 2000; Preston et al., 2007) of a small, but statistically significant, increase in cancer risk amongst atomic bomb survivors. Indeed, as early as 2000, the International Commission on Radiological Protection (ICRP) commented that, 'The absorbed dose to tissue from CT can often approach or exceed the levels known to increase the probability of cancer' (ICRP, 2000).

It is important to note here that, while there is considerable uncertainty about the most appropriate way to extrapolate radiation risks to doses below those that are epidemiologically accessible, the organ doses associated with CT are in a range which can be (and has been) studied epidemiologically (Pearce et al., 2012; Pierce and Preston, 2000; Preston et al., 2007). Thus, the debate, for example, about the validity of the 'linear no threshold' risk extrapolation, while pertinent to possible risks associated with conventional radiological examinations, is much less relevant for CT.

The individual risks associated with doses in the CT range are small. For example, for the subgroup of atomic bomb survivors exposed in the dose range from 5 to 100 mSv, the estimated attributable fraction (proportion of solid cancers attributable to the radiation) is only 1.8% (Pierce and Preston, 2000; Preston et al., 2007). Therefore, CT usage concerns largely relate to population risk and public health (a small risk multiplied by a large population subject to this risk), rather than to individual risks.

4. REDUCING THE COLLECTIVE DOSE FROM CT SCANNING

There are three ways to reduce, or at least stem the increase in, the collective dose resulting from CT usage without compromising patient care. These are: (1) reducing the dose per CT scan; (2) replacing CT scans with other imaging modalities, where possible; and (3) minimising the number of CT scans performed that are not medically necessary.

4.1. Reducing the dose per CT scan

There have been considerable technological advances in reducing the dose per scan (McCollough et al., 2009), which is especially important for children. This can be done either by manually adjusting the mAs settings for individuals of different sizes (Frush et al., 2002) or, as pioneered by Kalender et al. (2008), by automated current modulation. These automated techniques are now built in to most of the newer CT scanners, although how much they are being used is less certain (Hausleiter et al., 2009).

There is some evidence that doses per CT scan are decreasing. In a comparison of the settings used by members of the Society of Pediatric Radiology (SPR), Arch and Frush (2008) found that mAs settings decreased significantly between 2001 and 2006 for paediatric CT; they suggested that these changes may well be due to increased awareness of radiation risks. That said, members of the SPR are probably among the most aware of radiation issues of any physician group, so this decrease may not necessarily be generalisable.

4.2. Replacing CT scans with other imaging modalities

In appropriate situations, the two alternatives are magnetic resonance imaging (MRI) and ultrasound. The selective application of ultrasound for the assessment of paediatric appendicitis is discussed below. There are a variety of scenarios where MRI can replace CT without loss of efficacy (Deck et al., 1989; Ward et al., 1997; Clarke et al., 2001; Malfair and Beall, 2007; Semelka et al., 2007; Lin and Narra, 2008; Oikarinen et al., 2009), with common examples being imaging of the brain (Deck et al., 1989) and the lumbar spine (Malfair and Beall, 2007). A recent study (Oikarinen et al., 2009) suggested that one-quarter of CT scans in young patients could, according to the European Commission referral criteria (European Commission, 2000), be replaced by MRI examinations, assuming that MRI machines are available.

4.3. Potential for reducing or slowing the increase in CT usage

Are a significant number of CT scans being performed that are clinically unhelpful, which could potentially be eliminated without compromising patient care? This question can be assessed via the potential efficacy of clinical decision rules. A clinical decision rule is a tool designed to help clinicians make diagnostic and therapeutic decisions – in this case, providing sets of specific indications for which a CT scan is recommended. There have been many retrospective studies of the proportion of CT scans that could have been avoided if a high sensitivity clinical decision rule for CT scanning had been applied, where 'high sensitivity' means a decision rule that would not exclude any clinically useful scans (Smits et al., 2005; Stein et al., 2009). Typically, the number of CT scans can be reduced by at least 25% without compromising patient care.

As discussed below, similar potential CT usage reductions have been estimated for other diagnostic endpoints (Garcia Pena et al., 2004; Hadley et al., 2006). Common scenarios where there is scope for reduction in CT usage include renal colic (Broder et al., 2007), minor head injury (Klassen et al., 2000), abdominal pain (Smink et al., 2004), abdominal and chest trauma (Jindal et al., 2002), angiography for pulmonary embolus (Abcarian et al., 2004), and lumbar spine (Malfair and Beall, 2007).

5. PRACTICAL APPROACHES TO SLOW THE INCREASE IN CT USAGE

Whatever the actual proportion of CT scans that could potentially be eliminated, reducing or even slowing down the increase in CT usage will be an extremely difficult task for a wide variety of reasons. In particular, issues of patient throughput, legal issues, economic issues, and pressures from patients and parents all tend to mitigate against slowing or decreasing CT usage (Hendee et al., 2010; Hricak et al., 2011).

There are, however, approaches to reducing CT usage that are practical and will not compromise patient care. An example is in the assessment of appendicitis; this is of particular importance because it is typically a young person's disease. Until a few years ago, clinical observation and/or ultrasound were the standard tools to confirm the diagnosis prior to surgery. Currently, CT is the gold standard for diagnosing appendicitis, and in most institutions, more than 80% of patients have a CT scan prior to an appendectomy. An alternative approach is to use ultrasound initially; if the ultrasound is positive, an appendectomy follows, whilst if the ultrasound is negative or equivocal, a CT scan is performed. As shown by Garcia Pena et al. (2004), this can reduce CT usage by approximately 30%. More complex schemes are feasible with corresponding potential reductions in CT usage (Garcia Pena et al., 2004; Kharbanda et al., 2005).

5.1. Utility of clinical decision rules for CT

The American College of Radiology (ACR), the Royal College of Radiologists, and the European Commission have published decision rules (also called 'appropriateness criteria') for the appropriate use of CT (European Commission, 2000; Royal College of Radiologists, 2003; Amis et al., 2007), as have bodies associated with specific subspecialties (Ghanta et al., 2002; Stein et al., 2009).

As an example of their potential utility, Hadley et al. (2006) published a retrospective study of the ACR appropriateness criteria (decision rules) for trauma. They studied 200 trauma patients who had received some radiation imaging, in whom the imaging decisions were made without the use of decision rules. One hundred and sixty-nine patients had CT scans, with a total of 660 scans. If the ACR appropriateness criteria had been applied, 44% of the CT scans would not have been performed. None of the major injuries would have been excluded from CT imaging, but 11 minor injuries, none of which required follow-up, would have been excluded from CT imaging.

Another study of the potential utility of appropriateness criteria in high-tech imaging comes from Lehnert and Bree (2010). They reviewed 459 elective outpatient CT and MRI examinations from primary care physicians. Based on evidence-based appropriateness criteria, they concluded that 74% were appropriate and 26% were inappropriate.

5.2. Improving utilisation of clinical decision rules for CT

Clinical decision rules are a potentially powerful tool for slowing the increase in CT usage, because they have the potential to 'trump' some of the major factors that result in CT scans being undertaken when they are not strictly medically necessary.

In fact, in the examples discussed above (Hadley et al., 2006; Lehnert and Bree, 2010), clinical rules were not applied; this situation is often the norm (Bautista et al., 2009). For example, the results of a recent study (Eagles et al., 2008) of the

Canadian CT Head Rule (awareness: 66% in the UK, 31% in the USA; use of rule: 21% in the UK, 12% in the USA) suggest that there is considerable room for improvement in CT decision rule awareness and utilisation.

One way to potentially improve decision rule utilisation for CT imaging is to build them into computerised ordering systems. Such a system is in place at Massachusetts General Hospital (MGH; Sistrom et al., 2009; Vartanians et al., 2010); here, as a required part of the imaging order process, the physician inputs a set of signs/symptoms into the system, followed by the requested imaging test. The system responds with a quantitative assessment of the utility of the requested imaging test, together with a list of alternative procedures to consider, again with utility assessments. The physician is then free to proceed with, or change, the imaging request. At MGH, before these decision support rules were in place, outpatient CT volume was increasing by approxiamtely 13% per year; since these rules were put in place in 2005, CT usage has stayed approximately constant (Sistrom et al., 2009). Similar results have been reported from the Virginia Mason Medical Center in Seattle (Blackmore et al., 2011).

Whilst more studies on computerised decision support in the context of imaging are needed, the available evidence suggests that if decision guidelines are universally provided to the physician at the time of ordering a CT scan, and CT ordering patterns are audited regularly, the frequency of clinically unnecessary CT scans can be reduced. Specific decision guidelines, which will change with time as clinical evidence accrues, cannot and should not have the status of law, nor must the profession start down the road towards 'cookbook medicine' with mandatory protocols. However, access to, and consideration of, current imaging guidelines as support for the physician's imaging decisions could potentially be mandatory (Brenner and Hricak, 2010). This same guiding principle is part of the European Directives (Ringertz, 2000) that 'Member States shall insure that referral criteria for medical exposure ... are available to the prescribers of medical exposure'.

6. CONCLUSIONS

When a CT scan is clinically appropriate, the CT benefit/risk balance is by far in the patient's favour. However, if perhaps one in four of all CT scans are not clinically necessary, this results in a significant unnecessary collective dose and consequent unnecessary population risk. For example, in the USA, 20 million clinically unwarranted CT scans may be given each year. So, while CT risks are small, a small risk multiplied by many millions of clinically unwarranted scans may well translate into a public health concern some decades in the future.

The way forward involves reducing the dose per scan, an approach now vigorously adopted by manufacturers, and reducing the number of clinically unwarranted scans. The latter is a more difficult task, but the 'as low as reasonably achievable' principle demands that it be addressed.

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