BOOK REVIEWS

Annals of the ICRP, Publication 102, Managing Patient Dose in Multi-Detector Computed Tomography (MDCT) Radiation Dose from Adult and Pediatric Multidetector Computed Tomography COMARE 12th Report, The Impact of Personally Initiated X-ray Computed Tomography Scanning for the Health Assessment of Asymptomatic Individuals The Psychology of Risk

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Computed tomography (CT) is a complex x-ray technique which, since its inception in the 1970s, has transformed diagnostic radiology. In essentials, the technique involves combining high resolution digital data from a large number of multi-angle x-ray projections to produce a single three-dimensional data set, which, using the power of modern computer graphics, can then be viewed as a rotatable three-dimensional image, or sliced, magnified, enhanced and/or projected through any desired plane, currently down to millimetre resolution. The downside to these advances is that radiation doses to subjects from a single CT examination are in general significantly greater than those previously associated with simple x-ray examinations. But because CT is so powerful, so obviously ‘high-tech’ and often readily available, its use is expanding rapidly, not only to assist the clinical diagnosis of symptomatic patients, but more widely, including its use for routine health checks on asymptomatic subjects, particularly in the commercial sphere. In consequence, population doses from this source are becoming significant.

For example, in the USA some 75 million CT scans, averaging around 10 mSv effective dose each, are now carried out annually, resulting in an increase in population dose roughly equal to that already received from natural background radiation. In their separate ways, the three publications reviewed here make an informed and largely complementary contribution to the understanding of dose issues surrounding the burgeoning use of CT in the medical field.

The ICRP document (a monograph of around 80 pages) is an excellent and very readable summary of the main features and applications of modern CT, and intended to update their previous publication on the same topic (ICRP publication 87; 2000). The book summarises the current ‘state of the art’ in CT, and analyses dose issues in relation both to the available technology and to medical applications. The emphasis is on issues of dose reduction, through making effective use of the versatility and control provided in modern instrumentation, and justification, although restricting discussion of this topic to operational matters without straying far into areas of clinical judgement. The document is directed primarily at ‘imaging professionals’, defined as ‘radiologists, cardiologists, operators, medical physicists and researchers involved in patient dose management’, although the book has the wider aim of influencing physicians, hospital administrators and instrument manufacturers. The text is organised into four well set out chapters, describing in turn: CT principles and instrumentation, factors affecting radiation dose to patients, both instrumental and those under operator control (two chapters), and clinical issues of dose management. The complex problems involved in determining and specifying doses in CT are discussed in a technical appendix. Each chapter starts with a set of summary points, and although there is no index to the book, the chapter headings, sub-headings and summary points provide excellent signposting, and finding sections/topics is straightforward.

The first three chapters are largely technical, but pitched at a level which should be accessible and of value to physicians and others who, although non-specialists in radiology, need to make informed judgements concerning the use of CT. In chapter one, modern technology is described, and the dose implications of the evolution from single source, single detector CT scanning (SDCT), to multi-detector instrumentation (MDCT), are discussed. The most spectacular instrumental progress in recent years has resulted from advances in electronics, both in detector miniaturisation (and hence image resolution) and in speeds
of data transfer—a similar outcome to recent advances in digital camera technology. Modern CT instruments can handle and process data obtained simultaneously from arrays of up to 64 sub-millimetre solid-state detectors, and developments here are not static—it is suggested that arrays of 1000 or more detectors will appear in the next generation of instruments. The second and third chapters then deal with more specific technical issues: factors that increase or decrease dose in MDCT as opposed to SDCT, use of diagnostic reference levels, the trade-off between image quality and patient dose, equipment and operator choices that affect patient dose, optimisation of scan coverage and acquisition parameters, image reconstruction, and methods of improving signal/noise ratios. Recent developments have led to significant reductions in patient scan time, and enabled major improvements in image resolution and quality. But the point is made that unless radiologists and CT operators fully understand the particular characteristics of their instruments, and make full use of the controls available to them, radiation doses to individual patients may be unnecessarily high. Although, initially, the advent of MDCT systems sometimes resulted in increased radiation doses to patients, ICRP claim this was largely due to operators setting machine parameters primarily to optimise image quality, with lesser regard for patient dose. It is certainly now the case that modern systems can be optimised to achieve lower radiation doses compared to earlier single-detector systems for images of comparable quality. But, because instruments are capable of greater image quality (resolution, low noise, contrast, etc.) than is often needed, ICRP call for more attention by referring physicians to the precise specification of their imaging requirements. This would allow radiologists and CT operators to adjust protocols and instrumental parameters to achieve the required diagnostic quality whilst minimising patient exposure. ICRP also point to another pitfall, namely the uncritical use of ‘automatic exposure control’ (AEC). Modern instrumental software often provides an AEC facility, but using this is no substitute for a fuller understanding of instrumental capabilities. To quote: ‘AEC does not totally free the operator from selection of scan parameters, and awareness of individual systems is important’, and again ‘Understanding of some parameters . . . is not intuitive and introduces the opportunity for error’.

Reading between the lines, this is a warning to those who use such an instrumental or software ‘black box’ with insufficient understanding of its workings.

The final chapter, ‘Dose management in clinical practice’, is substantial (11 pages and over 70 references), and is primarily concerned with justification. The key point is made in the first sentence: ‘Justification is a shared responsibility between requesting clinicians and radiologists’. The first part of the chapter goes into considerable detail of exactly what justification means in this context, how this might be achieved, and why detailed justification is necessary. ICRP cite the US Consumer Bills of Rights and Responsibilities on Consumer Protection in the Health Care Industry, namely that the health care professional must ‘discuss all risks, benefits, and consequences of treatment or non-treatment’ with the consumer or patient. In contrast, it is related that in the USA under 15% of radiology departments currently inform patients about radiation risks, and only around 9% inform patients about possible alternatives to CT using non-ionising radiation. ICRP not only assert that the issues of patient information, discussion and informed consent are important, if largely neglected, but add the further claim that ‘there is a substantial lack of comprehension of CT radiation dose among requesting physicians’—and, presumably, a lack of understanding of the potential risks involved—which must in turn imply that justification for any particular CT examination will sometimes not be soundly based. To remedy this, ICRP recommend more and appropriate training in radiation protection for all groups involved, including physicians, cardiologists, radiologists and CT operators.

The remainder of the final chapter examines techniques, justification and dose reduction measures for a number of particular CT procedures, for example for chest and lung examinations, for colonography, for coronary calcium quantification, and for investigations involving children or pregnant patients. Useful tables giving typical doses for specific examinations are given, and practical means of dose reduction are discussed.

An excellent introduction to the ICRP’s book is provided by the ‘Guest Editorial’, which is, in itself, an authoritative mini-review of the actual and potential applications of CT, and the nature of some of the issues these applications raise. In particular, Professor Adrian Dixon picks out the need, expressed in the book itself, for the additional training of all workers involved in CT, with the clear implication that, in his view, this need is not at present being fulfilled. He concludes, somewhat cynically perhaps, but with the undoubted voice of experience: ‘While those responsible for an institution will happily pay several hundreds of thousands of dollars/euros for a new CT machine, those same individuals are often reluctant to invest much in radiographic training and continuing medical education, or in medical physics support to monitor the radiation aspects of CT.’

Overall, ICRP102 is a valuable, intelligible and thought-provoking book, which is likely to
interest all concerned with medical diagnosis and with the practicalities of CT scanning. In retrospect, I think there is surprisingly little attention given to the problems associated with the CT scanning of infants and children (only a small section in Chapter 4), although this appears to be one of the more pressing issues. However, overall this is an excellent and timely publication. To quote the Guest Editorial: ‘It is to be hoped that at least the summary points are read by the appropriate administrators’.

The Springer publication is considerably more weighty (270 pages in 16 specialist chapters), and although covering similar topics to the ICRP publication, each topic is considered at far greater depth. The book consists of an edited collection of articles by various authors, and in consequence is somewhat repetitive, each article being designed to be readable in isolation. Various chapters will probably appeal to individual CT practitioners as reference material. It is to be hoped too that instrument manufacturers will take more note of radiation issues in relation to the design of their instruments, as I gain the overall impression that modern developments have been rather too much directed at outsmarting competitors with technical wizardry, with lesser attention being paid to issues of patient exposure and dose reduction.

The first article, ‘Clinical expansion of CT and radiation dose’, serves as an introduction to the whole book, and discusses how the general principles of radiological protection can and should be applied in the medical application of CT. The importance of the ‘Linear No Threshold’ (LNT) hypothesis as the basis for the quantitative aspects of radiological protection, and in underlying the ALARA principle (‘as low as reasonably achievable’), is emphasised. After describing the recent clinical expansion of CT and the nature of the radiation problems thus created, the article focuses on the crucial roles of the referrer and the operator, respectively, in providing justification for any particular investigation, and of achieving the optimal dose reduction consistent with a specified clinical purpose. This chapter is a lucid and concise statement of the aims of the book, and is an excellent and very readable explanation of why these topics should be of concern, not just to radiologists, but particularly to referring physicians. Many of the key questions relating to justification are matters of clinical judgement on which only the physician has, or should have, the knowledge and experience to make decisions.

There follow seven articles in the first section of the book, under the general heading ‘Radiation Risks in Multidetector CT’. Curiously, the first two articles, on how cancer risks are associated with exposure to ionising radiation, take a step back and deal with the scientific assumptions which underlie radiological protection itself. The first of the two (Chadwick and Leenhouts) sets out to demonstrate that the LNT hypothesis is logically consistent with current theories of the effects of ionising radiation on cells, and the role of these effects in the causation of cancer. The second (Cohen) sets out, amongst other things, to discredit the LNT hypothesis, citing much observational data as supporting evidence. Whilst both chapters are interesting accounts of their respective topics, I think that, in debating the scientific fundamentals of radiological protection, these chapters are out of place here, irrespective of their merits. The aims and objectives of this book are essentially practical ones and the articles generally aimed at CT practitioners. As emphasised in the Introductory Chapter, the established system of radiation protection is the starting point for all discussion, and is not up for debate. These two articles deviate from the theme of the book, and it is not clear to me what purpose has been achieved by including them.

The remaining five chapters in Part One deal largely with technical issues, the trade-off between image quality (resolution, contrast, background noise, etc) and radiation dose to the subject. In particular, I found ‘CT parameters that influence the radiation dose’ (Nagel) and ‘Methods and strategies for radiation dose optimisation in MDCT with special focus on image quality’ (Tack) to be particularly informative. The chapter on ‘Automatic Exposure Control’ (Kalra) starts, as it turns out appropriately, with a quotation from Shakespeare: ‘Confusion now hath made his masterpiece’, and the well-written article shows why the provision of AEC may not be the blessing it purports to be. To add to the confusion, there appear to be substantial variations in nomenclature and methodology across different manufacturers, and AEC techniques are not necessarily transferable between instruments (a point also made in the ICRP publication). Kalra ends with a calculated understatement: ‘As with any new technique, there is a learning curve that radiologists and technologists must overcome in order to use these AEC techniques appropriately’. Yes, indeed!

Part Two of the book, ‘Clinical Approaches of Dose Optimisation and Reduction’, consists of eight medically more specialised chapters, the first five dealing with dose reduction in specific CT applications, to the head and neck, the chest, the abdomen, the skeleton, and in cardiac and vascular investigations. These chapters all appear to be informative and sufficiently comprehensive to be useful as reference material in their specialist fields. A further chapter deals with CT fluoroscopy, which is a technique allowing physicians immediate, real-time, feedback from CT images of various interventions, for example needle placement, core
biopsies, lumbar nerve root blocks and so on. In these techniques, radiation doses to staff as well as patients become an important consideration.

Then comes what may be the most important chapter in the book, dealing with dose reduction in the CT of children (Vock and Wolf). The authors point out that the biological effects of ionising radiation in infants and children are far more severe than in adults, mainly for the reason that proliferating tissues are much more vulnerable to the effects of radiation, and that proliferation is itself much more active early in life. For many other reasons, dose control during CT in children involves factors not so relevant in adults (e.g. irradiation of red bone marrow is more difficult to avoid in a small child). Additionally, justification of using CT at all requires specialised considerations not so applicable in adults; for example, as an alternative to CT, ultrasound examinations in children often are capable of image quality and resolution not achieved in adults, simply because the mass of intervening tissues is generally much less. The authors point accusingly to results of studies which estimate that around 40% of all paediatric CT examinations (and there are 4 million per year in the USA) are not clearly indicated. The implications are several: many physicians cannot be aware of the full implications of performing CT on children; in many cases equally suitable alternatives may not have been properly considered; and, as a consequence, radiological justification for many such examinations may well be meagre. It is noteworthy that the ICRP102 emphasises the same points, albeit more briefly.

The final chapter of the Springer book contains two articles, written collaboratively between four authors, and covers issues relating to radiation risks in low dose screening programmes for lung and for colon cancer. Such programmes raise justification issues also examined in the next document to be reviewed (COMARE), but in the present context the authors largely discuss examination protocols and options for dose reduction. The chapter on lung cancer screening includes a section on the combined use of positron emission tomography (PET) and CT, which is a very powerful technique for locating and identifying active tumours, but involves, in addition to the CT scan, the injection of a radio-isotope (usually fluorine-18). The range of application of this diagnostic technique is increasing rapidly, and clearly there are additional dose considerations from the use of the radioisotope. Again, these articles are likely to be valuable as reference material for specialists in these areas of medicine.

The third document, a Report by the UK Committee on Medical Aspects of Radiation in the Environment (COMARE), is of a very different nature. The Report was produced as advice to (UK) Government on the restricted issue of ‘the practice of personally initiated CT scanning of asymptomatic individuals’. That this is a rapidly expanding area of preventive medicine in the UK will be apparent from the advertisements in newspapers, or from a quick Internet scan with a search engine, and it is presumably the question as to whether these medical practices should be regulated which has led to the request from government’ for informed advice. The document is largely non-technical, but is finely argued and requires close attention by the reader.

The background to the report is explained in the short (3 page) Introduction, which relates the history of the invention and development of CT, the rapid expansion of applications and use of the technique, increasing awareness of the potential detriments from radiation exposure, and why scanning of asymptomatic individuals raises several issues not applicable to the use of CT in clinical diagnosis. However, this falls short of being adequate justification for the limited remit of this Report. COMARE state that CT scanning is ‘marketed directly to the public as a form of preventative medicine to give individuals peace of mind’, and it would seem that possible regulation of the commercial field may have been the impetus for requesting the advice of this report. However, whilst scans marketed to individuals fall into the category of being ‘personally initiated’, COMARE also state that around 90% of CT scans performed in the UK are undertaken on Health Service (NHS) patients, presumably for clinical purposes. If we could be sure that all clinicians making referrals were fully informed of the benefits, potential detriments and possible alternatives to CT, and thus that medical referrals were fully justified, one could perhaps accept the emphasis on ‘personally initiated’ CT scanning. But, as revealed by ICRP102, this situation is unlikely to be wholly the case. Why, then, spotlight the lesser problem? Undoubtedly there are problems with the widespread and increasing use of CT, but many of the issues discussed in the present Report must also apply to clinically requested CT, and it seems to this reviewer that it would have been greatly preferable for all these issues to have been taken together.

Following the Introduction, the COMARE Report contains eight chapters, covering the Rationale for the scanning of asymptomatic individuals (chapter 2), the scanning of specific anatomical regions (5 chapters), overall Conclusions, and finally a list of Recommendations (chapters 8 and 9, respectively). There follows an extensive list of around 200 references, and the usual COMARE Appendices (glossary of terms, lists of members, etc). Although there is no
The arithmetic is correct, the simple comparison of the numerical outcomes is misleading as it does not take account of the nature of the related benefits or detriments, inclusion of which may skew the picture. As a specific example, for the case of a CT scan of an asymptomatic patient (undertaken, say, as part of a health check to detect potential tumours), the occurrence of a positive result is likely to lead to the repeat of the scan and/or to the conducting of other diagnostic tests and examinations. A false positive will probably be identified as such, and the ‘detriment’ in that case would be limited to the radiation detriment of the one or more CT scans. On the other hand, if a negative result was not re-examined, and was in fact false, and if the undetected presence of the disease carried the possibility of major consequences (e.g. lack of immediate treatment of a tumour, possibly death), then clearly the ‘detriment’ would be very significant. The two types of result, both classed by COMARE as ‘detriments’, are not equivalent and should not simply be added together. I think that COMARE’s argument in this respect is simplistic, flawed and misleading, but unfortunately it underpins several of the Conclusions and Recommendations contained in the final chapters of the Report.

The Report’s thirteen Conclusions and nine Recommendations are stated clearly and concisely but, for the reasons given above, some may need to be treated with caution. For example, Recommendation 5 states: ‘...There is little evidence that demonstrates, for whole body CT scanning, the benefit outweighs the detriment. We recommend therefore that services offering whole body CT scanning of asymptomatic individuals should stop doing so immediately.’ But, in addition to this, the Report appears to stray into areas of social policy, where the issues become wider and the Committee are not necessarily equipped to consider them. Weighing potential detriment, possibly far into the future, against possible immediate benefit is surely a matter for an individual to decide, albeit under medical advice? In any event, the various factors will weigh differently for different age groups, and for individuals with different backgrounds, responsibilities and outlooks. On these matters, COMARE’s wisdom may be helpful, but the ultimate decisions involve social and political issues which are, or should be, outside COMARE’s remit. Thus, while medical and other scientific factors may lead to firm and logical conclusions, for which COMARE undoubtedly have the expertise and are entitled to make, the same is not necessarily true when considering recommendations which go beyond the medical science. COMARE quote the Council on Scientific Affairs: ‘It is important to balance the medical science, patient care, ethics..."
and economics of such tests’. One hopes that those in Government for whom this Report is intended will do just that.

Overall, how does one rate these publications? ICRP102: well written, concise, informative—strongly recommended as essential reading for CT professionals, clinicians and administrators. The Springer book: lengthy, detailed, comprehensive—recommended for radiologists and others as a work of reference. The COMARE Report: informative but lacking in quantitative information, restricted in remit and containing flawed reasoning (perhaps, like the curate’s egg, ‘good in parts’) — it should be read with circumspection, especially by those to whom its advice is directed.

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The Psychology of Risk
Glynis M Breakwell
Cambridge University Press (2007)

As a consequence of the adoption of the linear non-threshold model as a basis for radiological protection, we necessarily think in terms of the health risks of both occupational and environmental exposures to ionising radiations. However, risk encompasses many considerations other than health. Indeed, in the most general terms, risk can be characterised in terms of the frequency or probability of any adverse event and the deleterious consequences that would arise if that event were realised.

In the broad field of health and safety, we spend a large part of our time evaluating risks, considering trade-offs between risks and benefits, and communicating our evaluations to others. To perform these activities effectively, we need to be conscious of the multitudinous dimensions of risk, distinctions between objective risks, perceptions of risk, and the actions that individuals and organisations take in response to perceived risks, and the scope for affecting perceptions of, and attitudes to, risk by different approaches to communicating risk information. In all these areas, this new book by Professor Breakwell provides a treasure trove of stimulating ideas and relevant information.

In terms of characterising hazards, psychometric approaches began by using two-dimensional characterisation schemes, in which the axes are broadly described by two sets of characteristics. The first set is captured in terms such as voluntary or involuntary, delayed or immediate, unknown or known, uncontrollable or controllable, new or old, whereas the second set is captured by fatal or non-fatal, dread or common, catastrophic or chronic. However, Professor Breakwell emphasises that other factorisations and different dimensions of factorisation have also been identified, and that these analyses are based on ranking of risks, but do not address risk acceptability. Furthermore, the psychometric approach primarily addresses aggregated group views of hazards and does not address individual differences in risk perception. In this context, it is important to consider how differences in personality influence both risk perception and behaviour. An important point that is brought out is that psychological and material vulnerability are thought to be vital ingredients in determining the mental model of a hazard that an individual or group accepts or creates. Thus, for example, the less vulnerable might be more likely to accept a model of a hazard that posits that it can and will be controlled.

For those who have been involved in studies involving expert elicitation, much of the discussion on decision making covering heuristics and biases, and the effects of group dynamics, will be familiar. However, it is interesting to note the comment that many of the studies that have examined decision making in the presence of uncertainty have been concerned with the ways in which heuristics, biases, mental models and other factors affect risk estimation rather than choices. As Professor Breakwell comments, this raises the question as to whether such studies address decision making at all.

It is tempting to consider risk estimation and decision making in the presence of uncertainty to be rational activities, and that all that is required is to eliminate the various biases that can influence these processes. However, a chapter on risk and emotion serves as an appropriate corrective to this view. In terms of decision making, it has been found that, in a wide range of contexts, the emotional reaction at the moment is more influential in determining choice than the rational evaluation of options that was conducted beforehand. It has also been found that emotional reactions determine perceived risk rather than the reverse in respect of nuclear power plants, radioactive waste and radiation from nuclear weapons.

On risk communication, the transition in views is well captured by Fischoff’s brief history of the subject:

- All we have to do is get the numbers right;
- All we have to do is tell them the numbers;
- All we have to do is explain what we mean by the numbers;
- All we have to do is show them that they’ve accepted similar risks in the past;
- All we have to do is show them that it is a good deal for them;
All we have to do is treat them nice;
All we have to do is make them partners;
All of the above.

At the practical level, a detailed account is provided of the factors that influence how editors and journalists evaluate the factors that influence how they report stories about hazards and risks. Some aspects are well known, such as the journalistic usefulness of scare stories, the important role of infotainment, and the desirability of uncertainty in so far as it results in controversy. Perhaps less recognised are the important roles of individual journalists and editors, and the interactions between various media outlets. In respect of the latter, it is noted that scoops are good, but that scoops that nobody else follows up are not valuable. It is good to beat the opposition to a story, but not to be the only person who reports it.

A particularly topical aspect of the book is a discussion of various methods for consultation, participation and deliberation in risk communication. Referenda, inquiries, surveys, negotiations, consensus conferences and focus groups are all covered.

An interesting overall conclusion from the discussion on risk communication is how little is understood about communicating uncertainty. The author calls for the development of an analytic and explanatory approach that systematically explores the relationships between individual cognitive, emotional and motivational processes and social factors to enhance understanding of issues relating to the communication of both uncertainty and precautionary considerations.

The chapter on errors, accidents and emergencies focuses particularly on the Chernobyl accident. An important distinction is made between human errors and violations. This includes a discussion of the organisational contexts that make violations more likely or, in some cases, inevitable. On emergencies, an interesting comment is that emergency planning may have the effect of ‘normalising’ the emergency. Evidence is cited to show that emergency services that have planned for a threat and that have exercised their response, do not appreciate the full magnitude or demands of an actual emergency when it arises.

The discussion on risk management leads on to a useful account of the concept of a safety culture. This aspect is likely to be familiar of readers of this journal. However, the concluding section of this chapter, which deals with the creation and maintenance of trust, emphasises the important point that while having a safety culture is important, showing the world that you have such a safety culture is even more important.

A lengthy chapter on social amplification and social representation of risk seems to reflect some of the author’s central research interests. The detailed account of the Social Amplification of Risk Framework (SARF) left me feeling that this is a useful way to organise the analysis of a complex event and its aftermath, but I was not convinced that it contributes greatly to increased understanding, though the concepts of risk attenuation and risk amplification do provide a useful focus for planning.

Overall, I found myself very much agreeing with the author’s final conclusion. She writes that the idea that the psychological analysis of risk is capable of being transformed into a new technology for the deliberate, systematic and predictable restructuring of risk perception or acceptance is fanciful. Nevertheless, virtually all the data reported in this book can be translated into a hint or clue as to how risk responses can be changed. The author is well aware of the ethical implications of this conclusion and explicitly states that using, or making available for use, expertise in changing risk responses always has a moral dimension.

In summary, for anyone involved in risk estimation, risk communication or safety management, this is a really useful and thought-provoking book.

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