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Major trauma & cervical clearance radiation doses & cancer induction

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Summary

Aim: To compare the radiation dose of cervical spine clearance and body CT in a cohort of unconscious, major trauma patients for three different protocols, comparing spiral to multislice CT. To quantify the radiation exposure effect of the protocols on the lifetime cancer risk.
Method: The hospital trauma database was used to find the unconscious (GCS < 9), severely injured (Injury Severity Score >15) from 1 January 2001 to 31 December 2003, excluding isolated head injuries. The protocols used for imaging the brain and cervical spine were, including the radiographs performed as a mode:

(1) Three cervical radiographs (lateral, antero-posterior and open-mouth peg views) and CT of the brain and cranio-cervical junction.
(2) CT of the brain, cranio-cervical and the cervico-dorsal junctions with two radio graphs (lateral and antero-posterior).
(3) A lateral radiograph and CT of the brain and whole cervical spine. The dose of the initial body CT was recorded.

The exposure factors and field of view used were put into the Monte Carlo software, to estimate the CT and radiographic X-ray doses to the body as a whole and the dose to the thyroid associated with each region imaged. The associated nominal additional lifetime cancer risk was assessed.
Results: Excluding inter hospital transfers, where data was incomplete, 87 patients survived to be admitted and fulfilled the criteria. In 30 cases, the CT films were

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missing, the exposure factors were not recorded or no imaging was performed. In a further 21 cases, the X-ray packets were missing. Three patients had brain and cervico-dorsal CT imaging only, leaving 33 cases for evaluation.
The effective radiation dose for a spiral CT of the brain using the Toshiba Xpress GX CT scanner was 3.8 mSv. The total effective doses for imaging the brain and cervical spine using the three protocols with the same CT scanner were (S.D. as % of mean): (1) 4.4 mSv (5%), (2) 7.1 mSv (10%) and (3) 8.2 mSv (15%). The corresponding mean thyroid doses were: (1) 8.5 mGy (25%), (2) 48.9 mGy (20%) and (3) 66.5 mSv (20%). The resultant nominal lifetime cancer risks were: (1) 1:4500, (2) 1:2800 and (3) 1:2400. For the Siemens Sensation 16 multislice CT scanner, the total effective doses (S.D. as % of mean) were: (1) 2.3 mSv (10%), (2) 4.3 mSv (25%) and (3) 5.4 mSv (35%). The mean doses to the thyroid were: (1) 5.9 mGy (30%), (2) 36.1 mGy (50%) and (3) 52.4 mGy (40%). The lifetime cancer risks were: (1) 1:8700, (2) 1:4600 and (3) 1:3700.
Using the Toshiba spiral CT scanner, the total dose and additional lifetime nominal cancer risk associated with CT of the chest, abdomen and pelvis (CAP) as 16 mSv and 1:1250, respectively. Using the Siemens multislice CT scanner, these were 11.8 mSv and 1:1700. The cancer risk for protocol 1 when combined with a CT scan of the chest, abdomen and pelvis was 1:1000 for the spiral CT scanner and 1:1500 for the multislice CT (MCT) scanner. The cancer risk for protocol 2 with CAP CT using the MCT was 1:1200. The cancer risk for protocol 3 when combined with a CT scan of the chest, abdomen and pelvis was 1:1100 for the multislice CT scanner. Prior to the introduction of the BTS guidelines for cervical clearance, 12% of cases had CT of the body, which increased to 16% post-guidelines.
Conclusions: CT of the trunk (chest, abdomen and pelvis) is associated with the greatest risk of inducing a fatal cancer in the severely injured patient with a GCS less than 9. In our institution the multislice CT protocols expose the patient to less radiation than single slice CT, which is contrary to much of the published work to date. CT scanning the thyroid (or whole cervical spine) still has a marked effect on the cancer risk in cervical clearance.
Many centres will relax cervical spinal precautions in unconscious trauma patients if the cervical spine CT with reconstructions is normal. CT of the whole cervical spine may be justified in the unconscious, severely injured patient. In conscious trauma patients, the additional lifetime risk may not justify CT of the whole cervical spine as a routine practice.

Aim

An observational study to compare the radiation doses for radiological clearance of the cervical spine for unconscious (GCS < 9), major trauma patients from different British Trauma Society (BTS 2002) protocols[5]: conventional radiographs, CT of the brain and cranio-cervical junction; the above together with CT of the cervico-dorsal junction or CT of the whole cervical spine and a lateral radiograph. The initial CT evaluation of the chest, abdomen and pelvis, where performed was also evaluated.

To evaluate the effect at this centre of changing from helical or spiral single slice imaging to multislice CT (MCT) technology.

To quantify the radiation exposure effect of differing imaging protocols on the nominal lifetime cancer risk.

Background

Advanced trauma Life Support transformed the management of patients, but the multiply injured still have a high mortality.[2] In England and Wales, survival to leave hospital improved on average 6% per year from 1989 to 1994 according to the Trauma Audit Research Network (TARN), but suggests little improvement across the country since then up to 2000.[32] Multiply injured patients have high Injury Severity Scores (ISS)[8] and a high mortality, despite the increasing input of more senior doctors in A&E.[33] In Leeds, the survival of a patient with an ISS of over 15 improved from 52% to 76% between 1988 and 1993.[9] The overall incidence of cervical spine injury in multiply injured in level I trauma centres is low.[11,14,16,3,1] However, those with head injuries are at increased risk of such injury,[34,35] inversely proportionate to their level of consciousness.[14]

Radiation to the neck is not without risk, because the thyroid is particularly sensitive to radiation. Background radiation remains the largest source to an individual overall (although this is only an average for the UK population, and individuals may have more radiation from artificial sources than from background exposure). The rapid expansion in imaging,[30] particularly multislice CT,[12,6] means that the lifetime risk of inducing a cancer is also increasing rapidly.[17] CT is useful for imaging the cranio-cervical and cervico-dorsal junctions,[18,21] which are difficult to view adequately with plain radiographs. The use of brain CT has doubled following the introduction of NICE guidelines, but has halved the admission rate (9—4%) in teaching hospitals.[20] The limitations of plain chest radiographs (e.g. missing anterior pneumothoraces) and abdominal ultrasound (e.g. poor retroperitoneal visualisation) have led to an increase in requests for chest, abdominal and pelvic CT scans. The justifiable popularity of conservative management of intra-abdominal trauma especially hepatic and splenic injury particularly in children, relies on accurate CT diagnosis. Although initial cervical clearance protocols appeared incomplete,[36] it is now commonly accepted to perform a CT scan of the base of skull to C3, when the brain is scanned in the unconscious,[38,47] but there has been a move to CT the entire cervical spine and reduce plain radiography, with little regard to the radiation doses involved. Theoretical average radiation dose data obtained from standard CT protocols[46] (Appendix A) have been reported previously. In the current study, an assessment is made of radiation doses using exposure details from actual patient examinations and consequent nominal cancer induction risk produced by different imaging protocols that have been used to clear radiologically the cervical spine in unconscious major trauma patients.

Method

A set of unconscious major trauma patients identified from 1 January 2001 to 31 December 2003, in a previous study,[45] looking at the effect on cervical spine imaging after the introduction of the British Trauma Society guidelines for cervical clearance which was in our institution, when submitted for publication 23 September 2002.[5] The CT and radiography exposure data were obtained for the brain, body and three cervical spine protocols used: (1) cervical radiography and CT scanning of the brain and upper cervical spine or odontoid process; (2) an antero-posterior and lateral cervical spine radiograph and CT of the brain down to C3 together with the cervico-dorsal junction; (3) a lateral radiograph and CT of the entire cervical spine to the second dorsal vertebra and CT of the brain. This allowed measurements from the spiral CT (Toshiba Xpress GX, Toshiba Medical Systems, Manor Court, Manor Royal, Crawley, West Sussex, RH10 2PX) of radiation doses of the different protocols actually undertaken on our cohort of patients, using the old technology (helical or spiral). For CT examinations, this used the recorded exposure details (mA, kV, field of view, individual slice thickness) for each patient and for plain radiography dose average exposures were devised from the Trusts's published exposure factor audit data.[42] The total doses for the protocols were then calculated for the current 16 multislice CT (Siemens Sensation 16 slice, Siemens House, Oldbury, Bracknell, RG12 8FZ), and the doses compared.

Estimation of CT doses

The total effective dose and the dose to the thyroid gland were estimated for CT examinations of the body, brain and cervical spine for multiple trauma patients who underwent CT scans using the Toshiba Xpress GX (Toshiba Medical Systems, Manor Court, Manor Royal, Crawley, West Sussex, RH10 2PX) at the University Hospital of North Staffordshire between the dates of 1 January 2001 to 31 December 2003. Organ doses were estimated using the Monte Carlo techniques[29] and a software package designed for CT dosimetry (CT patient dosimetry Excel spreadsheet, version 0.99w, 2005. The CT dose index values Available from http://www.impactscan.org/).[25] Information required for the Monte Carlo simulation to be undertaken includes the exposure factors and field of view used and the Computed Tomography Dose Index (CTDI) for the CT scanner concerned.[57] The results of the simulation yield estimations of organ doses and effective dose. The Computed Tomography Dose Index (CTDI) values were taken from direct measurements made on the CT scanners and corrections applied for the slice thickness used. The films from the original CT scans for the patients allowed the length of the neck scanned or the field of view to be measured, for our cohort. The doses were calculated using individual exposure data for spiral CT examinations on the Toshiba scanner and each dose estimation was repeated for the Siemens Sensation 16 scanner using our current standard exposure factors employed on this scanner. This allowed evaluation of the same protocol on modern technology. The mean effective dose to the patient and the dose to the thyroid were calculated for each region imaged.

Estimation of plain radiography doses

The effective dose and dose to the thyroid gland was calculated for each radiographic projection using

Protocol	Number of patients	Brain (Toshiba)	Cervical spine CT (Toshiba)	Radiographs	Total (Toshiba)	MCT 16 Total (Siemens)
1	15	3.85 (± 2 %)	0.43 (± 30 %)	0.10 (± 75 %)	4.4 (± 5 %)	2.3 (± 10 %)
2	9	3.85 (± 2 %)	3.21 (± 15 %)	0.05 (± 70 %)	7.1 (± 10 %)	4.3 (± 25 %)
3	9	3.85 (± 2 %)	4.29 (± 25 %)	0.05 (± 100 %)	8.2 (± 15 %)	5.4 (± 35 %)

Figure 1 Mean effective dose in mSv for a group of patients undergoing three protocols on radiographic equipment and the Toshiba Xpress GX CT scanner. Rounded coefficient of variation (S.D. as a % of the mean) values are shown in brackets. The contribution to effective dose for the CT brain scan, and CT cervical spine on the Toshiba scanner and the radiographic examinations are shown separately. The effective dose is also estimated for the 16-slice Siemens CT scanner.

Monte Carlo techniques and a software package designed to model any plain radiographic exposure.[54] The exposure factors used were taken from standard exposure charts for the Accident and Emergency X-ray unit used. The effective dose and thyroid dose received by each patient for radiographic exposures were taken to be the number of exposures for each projection multiplied by the calculated standard dose for that projection and summed over all projections undertaken. (The record of rejected films was incomplete, so could not be formally included in the evaluation.)

Total dose

The total effective dose and dose to the thyroid received from both CT and radiographic exposures was calculated for each patient. The mean effective dose and the dose to the thyroid for each of the three cervical clearance protocols were computed.

Results

From 1 January 2001 to 31 December 2003, 87 unconscious, major trauma patients (ISS $>$ 15) survived to be admitted to the UHNS (excluding inter-hospital transfers) and 66 patient film packets were found (76%). Thirty either did not have a CT or did not contain the CT films or some films did not show the exposure factors used; there were all excluded. Three patients only had CT of the cervico-dorsal junction and are reported separately, leaving 33 complete data sets for analysis. Figs. 1—4 show the results of the estimation of effective dose and dose to the thyroid. Standard deviation (S.D.) values express the variation in the mean values due to random errors in the means. These do not include systematic errors in dose calculations such as calibration errors, drift in output from the X-ray generator and uncertainties in the Monte Carlo simulations. These systematic errors however will not significantly change the difference in estimated effective dose or thyroid dose between the three protocols or the two CT scanners.

All the brain CT effective doses were 3.8 mSv. The CT dose for the cranio-cervical junction was low (0.43 mSv), increasing to 3.2 mSv for protocol 2. This is more than for protocol 1 as the cervico-dorsal junction requires more X-rays to penetrate the thicker body region, as well as the peg.

The smallest contribution to effective dose and thyroid dose comes from the radiographic exposures which also show the widest dose variation between patients. The wide variation in dose between patients is due to the variation in the number of

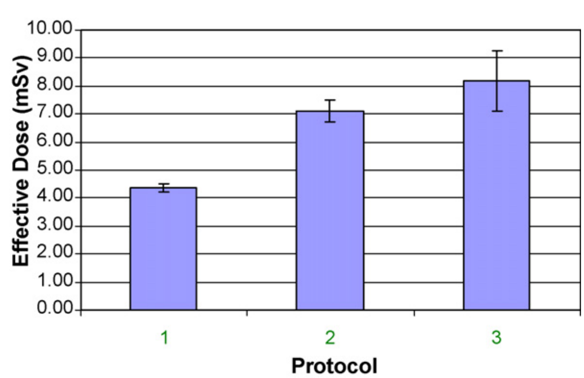

Figure 2 Mean effective dose to the body on the spiral Toshiba Xpress GX.

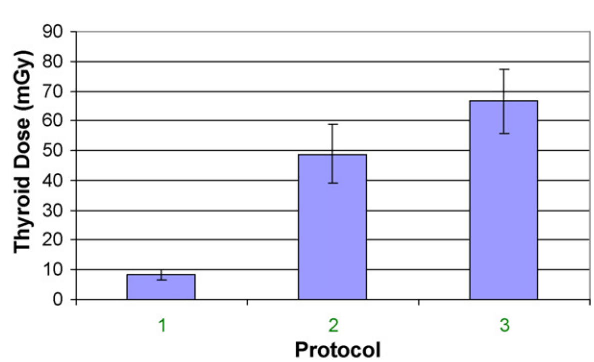

Figure 3 Mean thyroid dose from the spiral Toshiba Xpress GX.

Protocol	Number of patients	Brain Toshiba	Cervical spine CT Toshiba	Radiographs	Total Toshiba	Total MCT 16 Siemens
1	15	3.5 (± 1 %)	3.9 (± 35 %)	1.1 (± 70 %)	8.5 (± 25 %)	5.9 (± 30 %)
2	9	3.5 (± 1 %)	44.6 (± 25 %)	0.8 (± 65 %)	48.9 (± 20 %)	36.1 (± 50 %)
3	9	3.5 (± 1 %)	62.4 (± 20 %)	0.6 (± 90 %)	66.5 (± 20 %)	52.4 (± 40 %)

Figure 4 Mean dose to the thyroid in mGy for a group of patients undergoing three protocols on radiographic equipment and the Toshiba Xpress GX CT scanner. Rounded coefficient of variation (S.D. as a % of the mean) values are shown in brackets. The contribution to thyroid dose for the CT brain scan and CT cervical spine on the Toshiba scanner and the radiographic examinations are shown separately. The thyroid dose is also estimated for the 16-slice Siemens CT scanner.

radiographic projections actually performed on each patient from the previous observational study.[45]

Protocol 1: 3.3.3.1.1.3.0.3.1.3.3.3.3.3.4	NB: one patient did not have a lateral view
Protocol 2: 0.2.2.2.1.2.2.1 (not a lateral) 2	NB: two patients did not have a lateral
Protocol 3: 3.2.1.3.1.1.1.3.2	NB: all include a lateral

The contribution from the CT brain scans is the same for all protocols, but the contribution from CT of the cervical spine examination varies considerably between protocols. The mean effective dose for the Toshiba CT spine spiral scans only (part of protocol 1) was 90% less and 25% less for protocol 2 when compared with protocol 3 (see Fig. 1). The differences became slightly greater for the thyroid dose. When compared with CT of the whole cervical spine only as part of protocol 3, protocol 1 was 94% less and protocol 2 was 28%. Protocol 3 gives nearly double the dose compared to 1 for both helical & MCT or an eightfold increase to the thyroid from the spiral scanner or ninefold from MCT. The thyroid dose was much greater for protocol 3 than 1, as the whole thyroid is in the main X-ray beam for protocol 3 and the thyroid is just outside the main beam for protocol 1. The thyroid is partially in the beam for protocol 2. Prior to the BTS guidelines[5] 12% of our unconscious, major trauma patients had CT of the chest, abdomen and pelvis, but this increased to 16% for the subsequent cohort.[45]

Cancer induction risk factors

It is generally assumed that the risk of cancer induction increases in proportion to radiation dose. The International Commission on Radiological Protection (IRCP) have supplied figures which may be used for the purpose of risk estimation.[23] The assessment of risk is based on long term follow up of populations exposed to acute doses such as people exposed to the atomic bomb explosions in Japan. It has been suggested that uncertainties in cancer risk estimates may be about twofold higher or lower for acute doses and a further factor of two higher or lower for the projection of these risks to low doses and low dose rates. It should therefore be recognised that there are large uncertainties in the assessment of risk when using the nominal risk figures employed in this work.[24]

The effective dose values in Fig. 1 for a helical scanner provide an indication of relative doses and relative associated risks for the three protocols. The IRCP estimate the lifetime risk of fatal cancer induction in an adult population following exposure to low doses of radiation to be in the region of $5.0 \times 10^{-2}\,\mathrm{Sv}^{-1}$. Taking a risk coefficient of $5.0 \times 10^{-2}\,\mathrm{Sv}^{-1}$,[23] the lifetime risk of fatal cancer induction can be estimated as 2.2×10^{-4} (1 in 4500), 3.5×10^{-4} (1 in 2800) and 4×10^{-4} (1 in 2400) for protocols 1, 2 and 3, respectively, for the helical Toshiba Xpress GX. For multislice CT the lifetime cancer risk was 1:8700, 1:4600 and 1:3700 for protocols 1, 2 and 3, respectively. A typical helical (Toshiba) effective dose for CT of the chest, abdomen and pelvis is 16 mSv and 11.8 mSv for the multislice (Siemens Sensation 16). Risk increases linearly with effective dose,[39] which means that the CT exposure risk from the body CT scanning is summated with rest of the protocols exposures (see Fig. 5).

The three patients who just had radiographs, brain and cervico-dorsal junction CT had a mean effective dose from the helical Toshiba of 6.1 mSv and Siemens 4.1 mSv. This gave a nominal risk for the Toshiba at 1 in 3300, and the Siemens 1 in 4900.

Protocol	Radiographic (mSv)	CT C-SPINE (mSv)	CT BRAIN	Total (mSv)	BODY (mSv)	Total (mSv)	Additional cancer risk incl. body CT
1	3 films **0.1**	Helical (Toshiba) C0-3 **0.43**	Helical Brain **3.85**	**4.4**	Helical CT Chest, Abdomen, Pelvis +16	**20.4**	1×10^{-3} (1 in 1000)
1	3 films **0.1**	MCT (Siemens) C0-3 **0.31**	MCT Brain **1.89**	**2.3**	MCT C,A,P +11.8	**14.1**	7×10^{-4} (1 in 1500)
3	Lateral film **0.05**	MCT (Siemens) CO-D2 **3.45**	MCT Brain **1.89**	**5.4**	MCT C,A,P +11.8	**17.2**	9×10^{-4} (1 in 1100)

Figure 5 Comparison of effective doses in mSv for a helical and a multislice CT scanner of different protocols, also including body CT, with the associated additional lifetime risk of inducing a fatal cancer.

Discussion

Radiographs at the cranio-cervical and cervico-dorsal junction are often technically inadequate or incomplete.[40,58,15] Reconstructions (coronal and sagittal of the peg),[53] and thin slices (2 mm or less),[59] are needed for good quality CT scans with a high diagnostic impact.[19,43] Multislice CT (MCT) shows clear improvements in terms of speed and image quality over conventional CT[41] and is increasingly used in the unconscious[7,48,51] and severely injured patients.[50] There is a large literature suggesting that isolated ligamentous injury is rare,[11,22] but there are few studies of only obtunded patients. In a large series of obtunded trauma patients with a normal multislice CT of the cervical spine, subsequent MRI showed no ligamentous injury in 98.9% (362/366). Four had stable one column injuries, three disc abnormalities and few (1.9%) had SCIWORA (Spinal Cord Injury Without Radiographic Abnormality).[22]

The conventional five film radiographic series has a very low total radiation dose, even with repeats. The multislice CT dose may be less than conventional CT depending on the protocol and scanner, but the temptation to produce perfect thin slice images over more of the patient (Field of View) increase the total doses.[56] The larger area scanned may negate dose saving from the improved technologies including optimising exposures, better linear collimation and improved software. There are wide variations in doses delivered by individual CT scanners with effective doses varying between scanners of different makes by up to a factor of 10 for a group of commonly performed examinations in a recent survey of CT doses,[52] and also variation between the same model.[31] There are also marked radiation doses from different multislice scanners (dual or quad).[6] Clinicians have a very poor understanding of the actual radiation doses of procedures and the associated risks.[28,44] In addition, if the threshold for the use of body MCT drops and it proliferates at the expense of body US for the more minor cases, the final doses could be significantly higher than current practice, at an ever increasing total body dose of radiation. Fortunately only a relatively small number (12–16%) of our cases needed brain, cervical spine and body CT,[45] with the body CT contributing most of the dose. There appears to be a linear, cumulative and proportional risk of causing cancers over one's life time, and not a threshold effect as once thought.[4] It is important that we understand the effect of the radiation dose and how it changes with the exact technique of spine imaging used. The beam energy (kV), tube current and the time for which it is applied (mAs) and the film to focal difference need to be known to allow comparison of radiography doses between institutions (Appendix A). Similarly for CT the kV, mAs, slice width, overlap (pitch) and table feed all have an effect on the radiation exposure (Appendix A). Larger patients generally need higher tube currents.

The imaging quality of MCT is often much higher than is needed for confident clinical diagnosis. Thus, the use of "near", rather than true isotropic imaging is helpful in minimising the dose with no perceptible difference in image quality. Although the CT dose values vary between centres, doses can be optimised by collaborating between radiologists,[12,30] and/or medical physicists,[31] reducing doses by a factor of 7 for some examinations as reported from our institution. A pitch less than 1 causes overlap of the slices irradiated during a rotation and this overlap is reduced, then eliminated as pitch increases.[12,13] Differing body regions need varying techniques so for body scans a pitch of 1.5 and tube potential of 120 kV is ideal, whereas higher resolution is needed for brain scans so a pitch of 1.0 and a higher energy beam (140 kV) is used.[12] Areas with high inherent contrast (chest, spine and renal calculi) need lower mAs or tube current, allowing a reduction in the dose. Automated exposure control is the automated sensing of the exposure and appropriate adaptation depending on the body density, between rotations of the CT X-ray tube, altering the current (mA) depending on the patient's size. The cervical spine CT protocols require large radiation doses and still miss ligamentous injuries, so CT cannot be regarded as a gold standard for imaging in unconscious patients, and concerns about the radiation dose remain.[27] The average UK background radiation is 2.2 mSv per annum, and diagnostic X-rays have been calculated to make up between 0.6% (UK) to 1.8% in Europe and 3.2% in Japan of the cumulative risk of cancer to age 75, estimated from the Hiroshima bomb exposures,[17] accepting that these survivors were exposed to all types of radiation, including radionuclides. Thus, cervical clearance protocols can involve many years of background radiation but this is relatively small compared to body CT, at the initial stages of conventional CT assessment alone. We have not evaluated the number and doses of the follow up CT scans, which may be considerable.

Taking a snapshot with the Siemens Sensation 16, set up with the parameters in this Trust (Appendix A), delivers thyroid and effective doses approximately 50% less than the Toshiba Xpress GX, where the Toshiba had a relatively high dose for helical scanners, and the physicists have helped us to reduce the does at our institution.[31] Over the study period the use of body CT increased from 12 to 16%.[45] Figs. 1 and 5 compare doses for two individual scanners operating at this hospital only and therefore only illustrate the change in dose at this centre, where the new technology reduced the dose to the patient. National[52] and regional surveys of CT doses[60,52] have shown that, as a broad trend doses appear on average to be LOWER from single slice scanner than multislice scanners of 4 or more slices, although further survey data are required in order to clarify trends in dose due to changing technology. The same result was seen in a German survey.[6] The requirement to optimise the protection of patients and to set and review diagnostic reference levels[26,27] has led to a greater emphasis on efforts to reduce patient dose without compromising image quality. National reference doses have been recommended in the UK[52] for a limited number of CT examinations and continuous review is essential due to rapidly developing technology.[55] The close involvement of our physicists may explain why our MCT thyroid dose of the whole spine is relatively low (30 mGy versus 62 mGy helical). Chan et al. reported that CT of the whole cervical spine from helical scanners is 24.76 mGy to the thyroid and MCT 75.8 mGy from phantom data.[10] That is MCT increased the thyroid dose threefold over spiral (or helical) CT. In whole cervical spine CT the thyroid, which is particularly vulnerable to radiation, experiences a 14-fold increase in radiation dose compared to a three film X-ray series.[49] Our work shows considerable variation in doses according to the protocol used: radiographs, with CT of the peg and brain have a minimal effect on the lifetime risk of additional fatal cancers (1:4500), but this almost doubles for a lateral cervical radiograph with CT of the brain and whole cervical spine to D2 (1:2400).

The CT dose from examining the chest, abdomen and pelvis is the largest contribution, whilst CT of the base of skull to C3 is relatively small. In our institution changing from the helical (Toshiba) to the Siemens sensation 16 multislice reduced the total dose for protocol one from 20.4 to 14.1 mSv resulting in a reduction in cancer risk from 1 in 1000 to 1 in 1500. The Toshiba was a relatively high dose machine, compared to its contempories. In our institution we have around two hundred major trauma cases a year, so spine protocol 3 on our MCT would cause one tumour every 15 years (1:3700). If the body CT was added to every patient's dose then the MCT would cause a tumour every 5½ years (1:1100).

There needs to be a debate about risks and, cost benefits for each protocol option. The radiation dose even with repeated plain films is minimal from radiographs, but that from conventional spiral CT is so high that it is doubtful that whole neck CT can be justified in the conscious patient, but with the poor survival of unconscious patients[45] probably means that the risk for CT'ing the whole cervical spine is acceptable as so many die of their injuries. Modern MCT reduces the total dose for the whole body evaluation required for the multiply injured from 16 to 11.8 mSv (figures for this centre), but this remains the largest component in evaluation of the unconscious multiply injured initial assessment. The previously reported outcome in our unconscious major trauma patients showed that less than a quarter required CT of the chest, abdomen and pelvis.[45] This is fortuitous and may mean that CT of the whole spine is the most expeditious and appropriate protocol, potentially saving time in the golden hour.

This is the first paper to evaluate radiation doses of differing imaging protocols used for multiply injured, unconscious patients, and the effect on lifetime cancer risk, including the brain, spine and body scanning. These patients are among the most widely imaged of all groups, and particularly include young adults. It would have been better to have collected all the X-ray doses prospectively, so that we would have known exactly how many reject films there were and how long the studies took. We know that radiation doses for CT vary greatly in different units,[31] making guesstimates on standard protocols an inexact science and our work is a snapshot from our unit. We have not performed a formal risk/benefit analysis. On the other hand the literature in this field is sparse,[10,37,49,55] whilst CT use is increasing inexorably with little radiation data to guide decision making.

Conclusions

Knowing that the prognosis of unconscious major trauma patients is poor with few also needing body CT[45], and that the incidence of isolated cord and ligamentous injury is very low,[22] it appears justified to clear the cervical spine radiologically if the multislice CT is normal. This accepts that there is a small risk, probably around 1%, of missing a significant injury. In this group concerns about inducing thyroid tumours are relatively minor. However, in those who are conscious or GCS 9—12, the clinical evaluation is more likely to be helpful, the survival is good and the high risk of inducing a thyroid malignancy in a young cohort does not justify multislice CT of the base of skull to D1.

Recommendations

Combining the findings of a recent observational study[45] and this paper we suggest the following:

(1) Multislice CT of the base of skull to D4 is used in the unconscious major trauma patient to clear the cervical spine radiologically at the time of the brain CT. Cervical CT acquired at 2 mm and 1.5 pitch on a bony algorithm, with sagittal and coronal images of the cervical spine should be reconstructed from the data at 1 mm. This protocol may rarely miss isolated ligamentous injuries. Then revaluate the patient clinically when conscious.
(2) In the major trauma patients with mild to moderate alteration in consciousness (GCS 14—9), with a negative clinical examination of the cervical spine, an AP and lateral radiograph of the neck should be performed. Then CT of the brain down to C3 and any other poorly seen areas. Thus, if the cervico-dorsal area is not seen well on X-ray, then the brain SCOUT should continue down to D4 to allow accurate counting of the levels scanned by the CT.
(3) Do not forget to clear the whole spine, i.e. dorsal and lumbar in multiple trauma cases. The abdominal CT if performed at 5 mm can be re-processed down to 1mm and reconstructions made on a bony algorithm of the dorsal and lumbar spine in sagittal and coronal planes, similarly the bony pelvis. This should obviate the need for return trips to CT.

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Appendix A

The dose calculations are undertaken using dosimetry data for the North Staffordshire royal Infirmary, Toshiba spiral CT scanner.[46] All the doses supplied are estimates of dose using the factors and the dose delivered to an average patient attending some of our X-ray rooms.[42]

Typical exposure factors		Entrance surface dose (mGy)	Estimated effective dose (mSv)
Cervical spine radiographs			
AP (+grid)	70 kV, 12.5 mAs, 100 cm FFD	0.8 mGy	0.05 mSv
Lateral	70 kV, 12.5 mAs, 180 cm FFD	0.2 mGy	0.006 mSv
Peg	70 kV, 12.5 mAs, 100 cm FFD	0.9 mGy	0.005 mSv
Oblique	62 kV, 10 mAs, 100 cm FFD	0.44 mGy	0.02 mSv
Swimmer's view	76 kV, 65 mAs, 100 cm FFD	7 mGy	0.2—0.3 mSv
Lumbar spine radiographs			
AP	75 kV, 29 mAs, 100 cm FFD	3.4 mGy	0.3 mSv
Lateral	86 kV, 54 mAs, 100 cm FFD	12.6 mGy	0.3 mSv

Appendix A (*Continued*)

Typical exposure factors		Entrance surface dose (mGy)	Estimated effective dose (mSv)
Conventional spiral CT (Toshiba Xpress)			
C0—C3	120 kV, 150 mAs; pitch 1; 2 or 3 mm slices		0.34 mSv
C5—D2	120 kV, 150 mAs; 2 or 3 mm slices		2.2 mSv
C0—D2	120 kV, 150 mAs; 3 mm slices		4.3 mSv
Brain	130 kV, 300 mAs, 200 mA; 3 and 7 mm contiguous slice widths		3.8 mSv
Chest	120 kV, 130 mAs; 7 mm slice width pitch 1.5 mm		6 mSv
Abdomen and pelvis	120 kV, 130 mAs; 7 mm slice width pitch 1.5 mm		10 mSv
Multislice CT (Siemens Sensation 16)			
C0—C3	120 kV, 130 mAs (NB: may require up to 150 mAs); pitch 1 coll. 0.75 mm, 9 mm irradiated slice width		0.17 mSv
C5—D2	120 kV, 130 mAs (NB: may require up to 150 mAs); pitch 1 coll. 0.75 mm, 9 mm irradiated slice width		1.1 mSv
C0—D2	120 kV, 130 mAs (NB: may require up to 150 mAs); pitch 1 coll. 0.75 mm, 9 mm irradiated slice width		2.1 mSv
Brain	120 kV, 320 mAs; scan time 1 s; contiguous slices 6 mm (and 3 mm) imaged slice width coll. 1.5 mm (and 0.75 mm), 18 mm (and 9 mm) irradiated slice width		2 mSv
Chest	120 kV, 100 mAs; 6 mm slices width 1.5 mm collimation 18 mm irradiated slice width 30 mm feed approximately 36 slices above the diaphragm		1.8 mSv
Abdomen and pelvis	120 kV, 140 mAs; 5 mm slice width collimation 1.5 mm irradiated slice width 24 mm feed/rotation 24 mm approximately 92 slices below diaphragm		10 mSv

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