Establishment of diagnostic reference levels for CT trunk examinations in Saudi Arabia.

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Aims and objectives

As CT is the largest source of population dose from medical radiation, optimisation measures within the modality are crucial to ensure appropriate use and avoidance of unnecessary radiation exposure. Diagnostic reference levels (DRLs) are an important optimisation tool, which help identify abnormal high doses. DRLs are currently not available in Saudi Arabia, hence this research attempts to remedy this.

Methods and materials

Introduction

The number of requested Computed Tomography examinations is rapidly growing within diagnostic imaging. With the ongoing technological advances in MSCT, which makes it an exceptionally valuable diagnostic imaging modality, there might be potential for inappropriate usage of CT on patients, resulting in unnecessary exposure of radiation dose. CT has been reported as being one of the largest sources of medical radiation when compared to other modalities such as plain radiography [1]. Therefore, radiation protection is especially important in CT as it is attributed to almost half of the total collective dose from medical radiation [2]. Currently, there is no available data on radiation exposure delivered to patients in Saudi Arabia, although radiobiology researchers have addressed the association between the relatively high doses from CT and stochastic and deterministic effects [2].

Therefore, optimisation process should take actions to reduce radiation dose to patients undergoing CT examination to comply with the 'As Low As Reasonably Achievable' (ALARA) principle. To comply with such principles, dosimetry surveys need to be undertaken to measure dose distribution over wide geographic regions [3]. Studies such as the establishment of Diagnostic Reference Levels (DRLs) can be considered as a first step of optimisation to correct dose delivery variations [4]. To identify unusually high radiation doses, DRLs were defined by the ICRP in 1996 as being a form of investigation level to do so [5]. Due to the wide variations of CT dose delivery identified by dose surveys, establishing DRLs is a useful optimisation method that can increase awareness of dose levels being used, encourage optimization amongst CT centers and reduce the dose distribution [5].

In 2000, as per national regulations, the implementation of DRLs became a requirement at the European level [6]. Subsequent surveys were carried out in different European countries, such as the UK and Ireland to name but a few [8] [10]. In the UK, for example, a 50% reduction in average dose between 1985 and 2000 has been achieved because
of the use of DRLs [Wallace, 2010 #44][3] [7]. The purpose of this study was to identify the current practice employed in Saudi Arabia in terms of CT radiation dose distribution and then to establish DRLs for CT trunk examinations for adult patients.

**Methods and materials**

Ethical approvals were sought from the Institutional Review Board (IRB) in the educational institute as well as hospitals participated in the survey. Currently, there are thirty hospitals in the western region of Saudi Arabia and all of them were contacted and 20 hospitals agreed to participate in this study. Five types of examinations namely, routine chest, high resolution chest (HRCT), pulmonary angiography (CTPA), abdomen and pelvis (AP) and the combined chest abdomen and pelvis (CAP) CT examinations representing patients' trunk were chosen for the study.

Survey booklets were designed and distributed to each CT centre and CT radiographers were asked to complete them. This includes collecting baseline information related to routine CT departments' protocols designed for average sized patients, including scanning parameters, such as detector collimation, slice thickness, tube current, tube potential, tube rotation time, pitch and scan range.

Radiation dose recordings; Volume Dose Index (CTDIvol) and Dose Length Product (DLP) for a minimum number of ten adult patients of average size (60-80kg) presenting for these five CT examinations were also recorded by the examining radiographers over a period of seven months June 2013 to January 2014. CTDIvol in milligray (mGy) is used to express the absorbed radiation dose in a cylindrical shaped phantom for a specific volume slice computed tomography dose index (CTDI), whereas DLP in milligray per centimetre (mGy.cm) is the CTDI volume multiplied by the length of the scan [8]. Weight (kg) for those patients was collected by CT radiographers using digital scale to determine average size patients.

Descriptive statistics of the dose distribution found across CT scanners surveyed in DLP (mGy.cm) and CTDIvol (mGy) were used to determine mean, minimum and maximum values. All calculations were performed using Excel 2011 for Mac (Microsoft, Redmond, WA, USA). Mean values for each site were calculated and 75th percentile of DLP and CTDIvol were used as a basis for DRLs (Table 1). DLP and CTDIvol were averaged for each site and 75th percentile was calculated as local DRL.

**Results**

**Results**

From the 20 participating hospitals with an installed base of 20 scanners, 12 hospitals representing 40% of all hospitals available in this province submitted complete and valid
data for 470 standard sized patients. Various types of scanners are available in those hospitals ranging from 16 to 128 slices brought by different vendors SIEMENS, General Electric (GE) and Philips (Figure 1). The dose distributions across the 12 clinical centres are displayed in Figure 2, with the DRL being identified by the broken line. The proposed Saudi DRLs are also compared with some published EU studies in (Table 2, 3, 4, 5, 6).

**Discussion**

CT is one of the most important imaging tools in diagnostic radiology. Faster acquisition time has made this technology the method of choice for diagnosing various pathologies. CT however is considered a high radiation dose modality therefore establishment of DRLs is highly recommended [9]. DRLs for CT are useful tools for lowering radiation levels [5]. These numerical values can be considered as simple indication of abnormally high doses, which can alert radiographers to take corrective action when high radiation doses are being delivered [10]. This identifies the departments that lie above the DRL. Since the DRL will always be breached by 25 per cent of the population, the DRL should be used as an indication, rather than a proof of excessive dose [3]. Also DRLs can be used as a guide to good or bad practice because when good and normal practice regarding diagnostic and technical performance is applied these levels are expected not to be exceeded for standard procedures [5]. In this study dose measurements on 12 CT scanners in Saudi Arabia involving five routine CT examinations have been performed in order to evaluate their performance and to produce a preliminary set of data for the establishment of diagnostic reference levels.

The five examinations included in this study were chosen because this is the first stage of a larger study aimed at optimisation for CT trunk examinations in Saudi Arabia. Furthermore, CT scans in the trunk region can result in the higher effective doses, which can reach estimated maximal values of the order of 15 mSv compared with 12 mSv in this study [10]. However, the establishment of DRLs is usually based on the frequency of use in clinical practice as recommended by ICRP [5].

DRL methodologies are based on standard size patient and to determine this for such dose reduction studies, weight was used as an indicator of patient size [11]. CTDI and DLP were recorded for each patient because they are proposed as the appropriate dose quantities for the establishment of diagnostic reference levels for optimising patient exposure [12]. To allow CT departments to compare their dose levels to national or regional standards in order to encourage them to improve their scanning parameter selection and thus radiation dose delivered as recommended by ICRP [5], individual results along with proposed national results were sent back to these centres for comparison.

Wide dose variations were noted across the departments surveyed for all examinations (Table 1), with a fold change of 43 in range DLP (59-2584 mGy.cm) reported for the examinations surveyed. The reasons behind this variation were caused by different
techniques, protocols and different settings of dose reduction software used [12]. Although Automatic Tube Current Modulation (ATCM) software was employed in all scanners, which can keep noise constant and reduce radiation dose during scan [13], different selections of image quality required by each department can lead to such variations in dose delivery because when lower than necessary noise level is requested, higher doses are delivered. The incidental high figures for the ratio between the minimum and maximum dose range can also be attributed to heterogeneity in examination techniques such as when spiral versus sequential HRCT of the lungs are used in some centres without the others. In this study the latter axial technique for HRCT was only performed in hospital 5 which had the lowest DRL and mean values of 139 and 115mGy.cm respectively compared with other centres (Figure 3). The implementation of iterative reconstruction algorithm can also play an important role in causing this variation among different sites where being installed in some scanners without the others. This was clearly noticed in hospital 4, which was the only hospital using this algorithm, where a huge dose reduction was achieved for all examinations surveyed (Figure 2, 3, 4, 5, 6). This algorithm can reduce image noise and provide images with good quality similar to or better than those of routine dose CT with filter back projection but with dose reduction of up to 50% [15].

Inter hospitals comparison with regard to proposed DRL for all examinations being surveyed (Figure 2, 3, 4, 5, 6) shows that almost 30% of hospitals in this study exceeded the DLP set as the DRL. Comparison of these data with other CT dose surveys is given in Table 2. Doses are higher than established in the Irish survey from 2010 [10]. For chest and HRCT examinations, the former DRLs were higher than the latter by almost 70% and 50% respectively, while for CTPA Saudi DRLs were comparable to the results from the Irish surveys. Finally, for abdomen and pelvis and CAP examinations the former DRLs still above the achievable levels set in Irish DRLs by almost 70%. Comparison of the results of the survey with the one in the UK is given in (Table 2). The values of Saudi DLP data are still above the achievable levels set in the British DRL [8] for HRCT, abdomen and pelvis and CAP, while for chest, Saudi DRLs were comparable to the one in the UK, indicating that the hospitals included in this survey can improve patient dose by optimising their CT protocols as these variations can largely attributed to this factor.
**Figure 1.** Frequency of CT scanners categorised per manufacturer and number of data acquisition channels.

Fig. 1
Table 1. Descriptive statistics of the dose distribution found across the 12 CT scanners surveyed in DLP (mGy·cm) and CTDIvol (mGy).

<table>
<thead>
<tr>
<th>Exam</th>
<th>Mean DLP (mGy·cm)</th>
<th>Range DLP (mGy·cm)</th>
<th>75th Percentile DLP (mGy·cm)</th>
<th>75th Percentile CTDIvol (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>414</td>
<td>101-1635</td>
<td>575</td>
<td>17.44</td>
</tr>
<tr>
<td>HRCT</td>
<td>274</td>
<td>59-1068</td>
<td>537</td>
<td>20.46</td>
</tr>
<tr>
<td>CTPA</td>
<td>267</td>
<td>61-1080</td>
<td>459</td>
<td>15.93</td>
</tr>
<tr>
<td>AP</td>
<td>646</td>
<td>180-1772</td>
<td>818</td>
<td>16.71</td>
</tr>
<tr>
<td>CAP</td>
<td>847</td>
<td>299-2584</td>
<td>1104</td>
<td>16.8</td>
</tr>
</tbody>
</table>

CTDIvol, CT volume index; DLP, dose-length product; HRCT, high-resolution CT; CTPA, CT pulmonary angiography; AP, abdomen and pelvis; CAP, chest, abdomen and pelvis.
Fig. 2
Fig. 3
Fig. 4
Figure 2. Dose-length product (DLP) distribution for examinations surveyed. (a) DLP distribution for chest CT examination; (b) DLP dose distribution for high resolution chest CT (HRCT) examination; (c) DLP dose distribution for CT pulmonary angiography (CTPA); (d) DLP dose distribution for abdomen/pelvis CT (AP) examination; (e) DLP dose distribution for chest, abdomen/pelvis CT (CAP) examination.

Fig. 6
Table 2. Comparison of DRLs [CTDIvol (mGy) and DLP (mGy cm)] with some European countries.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>DLP</td>
<td>CTDIvol</td>
<td>DLP</td>
</tr>
<tr>
<td>Chest</td>
<td>575</td>
<td>17.44</td>
<td>390</td>
</tr>
<tr>
<td>HRCT</td>
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<td>20.46</td>
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<tr>
<td>CTPA</td>
<td>459</td>
<td>15.93</td>
<td>430</td>
</tr>
<tr>
<td>Abdomen/Pelvis</td>
<td>818</td>
<td>16.71</td>
<td>600</td>
</tr>
<tr>
<td>CAP</td>
<td>1104</td>
<td>16.80</td>
<td>850</td>
</tr>
</tbody>
</table>

CTDIvol, CT volume index; DLP, dose-length product; HRCT, high-resolution CT; CTPA, CT pulmonary angiography; AP, abdomen and pelvis; CAP, chest, abdomen and pelvis.
Conclusion

The results showed significant variations in dose values among the CT scanners, which can be mainly attributed to variations in the examination protocols and the different kinds of scanners capabilities. Significant overdosing compared with the proposed DRLs has been noted, where almost 30% of the scanners exceeded the corresponding DLP value and this shows an urgent need for optimisation to improve distribution of observed doses for CT examinations in Saudi Arabia.

Personal information

References

References:


