Alfred Health's CT quality control program

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Aim

- A quality control (QC) program for computed tomography (CT) scanners is an important method of identifying issues and optimising radiation dose and image quality.
- Alfred Health Radiology operates five CT scanners of various models across two campuses for diagnostic imaging.
- Our aim was to develop a multi-faceted, multi-disciplinary, centralised approach to QC that could be used across all scanners in the health service.

Methods and materials

- We reviewed current QC tools and methods to develop a comprehensive QC program across all CT scanners.
- Regular (daily) and infrequent QC activities were structured to be consistent across scanners.
- Each manufacturer’s manual was evaluated to ensure that recommended QC methods were followed.
- A centralised system of recording results for QC was developed.
- To ensure that the comprehensive QC program led to optimisation, a method of discussing results and implementing change was established.
- After several months of establishing the comprehensive QC program, results were reviewed.

Results

- The QC items included in the comprehensive CT QC Program included:
  - Daily noise and uniformity checks
  - Annual Diagnostic Reference Level (DRL) audits
  - 3-yearly Image Review audits
- A CT Round Table group was established to meet several times throughout the year to review QC results, discuss optimisation strategies, evaluate new ideas and implement change. This group consisted of medical physicists, radiologists and radiographers.

1. Daily QC

- Daily noise and uniformity checks are undertaken by radiographers using the manufacturer’s quality assurance (QA) phantom and instructions.
• When results are out of tolerance they are immediately escalated to the
  supervising radiographer and medical physicist.
• These checks provide a method of predicting the need for an unscheduled
  service and ensuring that the systems remain within manufacturer
  specifications.
• Image quality degradation could be observed over time and pre-emptive
  actions were taken avoiding out of tolerance results (see Case Studies).
• Changes to the CT systems, such as major power outages, that may have
  consequences for image quality, were clearly evident using this tool (see
  Case Studies).
• **Case Study 1:** Figure 1 shows a region of interest (ROI) placed in the
  centre of a homogenous phantom with the mean value of the CT number
  increasing over time. This was due to a calibration not being performed
  when the CT scanner was installed. The incorrect calibration factors were
  being used in the 'daily fast cal'. The CT scanner was recalibrated by the
  engineers and the values were again within tolerance.
• **Case Study 2:** Figure 2 shows the mean CT number in a centre ROI
  significantly increasing the day after a major three day power outage at the
  entire site. This was due to the detectors not having warmed up sufficiently.
  The following day, once the machine was allowed to completely warm up,
  the values returned within limits.

2. DRL Audits (Optimisation)

• The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)
  Australian National Diagnostic Reference Level (NDRL) survey tool was
  identified for use for DRL audits for dose optimisation [1].
• The Australian NDRL survey is completed annually by the radiographers
  and coordinated and submitted by the medical physicist.
• The Australian NDRL survey allows comparison with the current Australian
  NDRLs as well as tracking doses over time to identify any changes and
  areas of concern.
• Figure 3 shows the Australian NDRL survey results from 2011 to 2013 for
  four of our CT scanners.
• **Case Study 3:** In 2011, it was identified that the dose metric CTDI
  (computed tomography dose index) for head scans on both the Emergency
  Department CT scanner and the Inpatients CT scanner exceeded the
  NDRL (Figure 3). This was due to the head scans being performed at 140
  kV. It was decided by the Round Table to trial a reduction to 120 kV. In
  2012 and 2013, the CTDI values fell below the NDRL values. The CTDI
  value of the Inpatients CT scanner reduced again in 2013. This was due
  to the replacement of the CT scanner and newer technology (iterative
  reconstruction) being used.
• **Case Study 4:** Figure 3 shows that the CTDI value of the abdomen/pelvis
  scan at the community hospital exceeded the NDRL in 2012. The average
weight of patients surveyed increased from 71 kg in 2011 to 76 kg in 2012 which may have had an impact on the CTDI value. The Round Table compared the protocol at the community hospital with the Outpatients CT Scanner at the metropolitan hospital as they were the same make and model. The iterative reconstruction settings were also investigated. The CTDI value returned to below the NDRL in 2013, although the cause was inconclusive, despite the average patient weight increasing to 79 kg.

3. Image Review Audit (Image Quality)

• The Royal Australian and New Zealand College of Radiologists (RANZCR) CT Image Review Self Audit was identified for use to assess image quality [2].
• RANZCR provides templates with a scoring matrix for general exams of the brain, lumbar spine and chest and for discal herniation of the lumbar spine.
• The patient and scanning data is collected by the radiographers, the images are then scored by the head radiologist of CT against the RANZCR matrix. This process is coordinated by the medical physicist. The results are assessed by the Round Table.
• The Image Review Self Audit allows image quality to be tracked over time and to identify any areas of concern.
• **Case Study 5:** Table 1 shows the results for five patients undergoing general scans of the chest on the Outpatients CT scanner. The clinical results were assessed by a radiologist and the dose metrics by a medical physicist. All five patients have a common failed criteria of "visually sharp reproduction of the segmental bronchi". This is because standard chest scans with a lung reformat were included in the dataset assessed. This reformat does not provide visually sharp reproduction of the segmental bronchi as it is not required to answer the clinical question. If visually sharp reproductions of the segmental bronchi are required then high resolution reformats are performed off the dataset. Patient 1 and 4 exceeded the ARPANSA NDRL due to positioning and patient habitus, respectively.
• It is noted that RANZCR have reviewed their worksheet since this audit was last performed and now includes a high resolution chest scan and no longer includes the abovementioned criteria.

4. CT Round Table

• The CT Round Table meets quarterly and includes radiographers, radiologists and physicists.
• The Round Table reviews QC activities such as the ARPANSA DRL Survey and the RANZCR CT Image Review Self Audit.
• It also addresses any protocols of concern and works towards the optimisation of CT.
The Case Studies discussed above were all reviewed by the Round Table group.

Images for this section:

**Fig. 1:** Mean CT number of a ROI placed in the centre of a homogenous QA phantom in a newly installed CT scanner that had not been calibrated at installation on site. The red lines indicate the manufacturer recommended tolerance levels. Inset: ROI placed in the centre of a CT image of a homogenous phantom.
**Fig. 2:** Mean CT number of a ROI placed in the centre of a homogenous QA phantom before and after a major three day power outage. The red lines indicate the manufacturer recommended tolerance levels. Inset: ROI placed in the centre of a CT image of a homogenous phantom.
Fig. 3: ARPANSAN DRL Survey results for six protocols across four scanners from 2011 to 2013. NDRL = National Diagnostic Reference Level (75th percentile of the spread of Facility Reference Levels (FRL) for each habitus/protocol). FRL = Facility Reference Level (median of the spread of Volume Computed Tomography Dose Index (CTDIvol, mGy) of a survey conducted by a facility with a minimum of 10 patients).
<table>
<thead>
<tr>
<th>Image Quality Criteria</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
<th>Patient 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualisation of entire thoracic wall</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visualisation of entire thoracic aorta and vena cava</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visualisation of entire heart</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visualisation of entire lung parenchyma</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>media</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>thoracic aorta</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visually sharp reproduction of the anterior mediastinal structures, including thymic residue (if present)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visually sharp reproduction of the trachea and main bronchi</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Visually sharp reproduction of the paratracheal tissue</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visually sharp reproduction of the carina and lymph node area</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Visually sharp reproduction of the oesophagus</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Visually sharp reproduction of the pleuromediastinal border</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visually sharp reproduction of large and medium sized pulmonary vessels</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Visually sharp reproduction of segmental bronchi</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Visually sharp reproduction of the lung parenchyma</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>border between the pleura and the thoracic wall</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Dose Information</strong></td>
<td>Patient 1</td>
<td>Patient 2</td>
<td>Patient 3</td>
<td>Patient 4</td>
<td>Patient 5</td>
</tr>
<tr>
<td>Below ARPANSA NDRL value</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Table 1:** Results from the 2012 RANZCR Image Review Self Audit for five patients undergoing a general scan of the chest performed on the Outpatients CT scanner.
Conclusion

- Dose and image quality issues can be identified through many different mechanisms, from daily exercises to three yearly audits.
- Having a multi-faceted, multi-disciplinary Round Table ensures tracking and resolution of any issues that may arise from these QC activities.

Personal information


References