When efficacy meets efficiency and compliance

This article summarizes the proceedings of the recent symposium sponsored by Bracco Imaging at ECR 2017 on the optimization of CT imaging. Chaired by Prof Thomas Albrecht, the symposium featured presentations by three clinicians highly experienced in the optimization, application and regulatory implications of modern CT imaging.

Chairman's introductory remarks

Prof Albrecht welcomed the audience to the Bracco-sponsored symposium on CT by reminding them of the central "workhorse" role of CT in modern imaging and clinical diagnosis. It's now 40 years since the Nobel Prize was awarded to Godfrey Hounsfield for his invention of CT, but development of the technique hasn't stopped–scanners are today much faster, have higher resolution, and permit high quality imaging at lower radiation dose. Inevitably however, these developments have resulted in CT becoming more complex. Current challenges focus on optimal scanner configuration especially in the quest to reduce radiation dose. It shouldn't be forgotten that CT is the biggest single contributor to overall radiation exposure in diagnostic medicine.

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Iodinated contrast media are fundamental to most CT examinations and a great deal of work has looked at optimizing contrast protocols and system settings, not only to improve image quality but also to reduce dose.

High concentration contrast media in clinical routine: possibilities for radiation dose and contrast media reduction

Prof. Tobias Bäuerle

Prof Bäuerle's starting point was in emphasizing the need to individualize CT protocols as much as possible. Two factors play a key role in such individualization. namely contrast medium administration and radiation optimization.

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Typically, contrast medium (CM) formulations containing between 300 and 400 mg Iodine/mL are used in routine CT examinations, with the high end of this range being known as High Concentration Contrast Media (HCCM). HCCM are beneficial in that both the volume and injection rate can be reduced while still administering the same amount of iodine. The greater flexibility of HCCM in terms of injection protocol means that radiation dose can be reduced in certain applications such as CTA while maintaining the same signal-to-noise ratio. All this is to the advantage of the patient, with a lower risk of CM-induced nephropathy, lower volumes of CM and the possibility of lower radiation dose.

BASIC PRINCIPLES

In the interplay of CM, radiation dose and image quality, the basic principles are worth recalling.

The number of X-ray photons delivered in CT depends on the tube current (mA) and exposure time (s) and increases linearly with increasing mAs. The number of photons is directly proportional to the applied radiation dose. Conversely, the kVp determines the energy of the photons delivered. Lowering the kVp will lower the energy of the photons delivered but not their number. A common misconception is that the lower energy of the delivered photons is the reason for the radiation dose reduction potential of low kVp examinations in CT. However, the actual reason the radiation dose is lower at low kVp is that the number of photons generated by the CT tube is lower at low kVp than at higher kVp when the same mAs value is used. This is primarily for technical reasons such as the lower effectiveness of the tube at low kV and stronger filtering of low-kV photons.

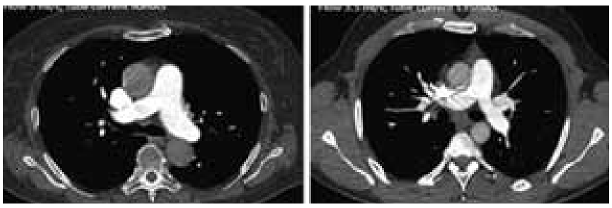

Figure 1. There are many parameters such as kV, mAs and contrast media. The above example is CT angiography using a HCCM and low mAs prtotocol. Left Panel: High flow (5mL/s) of Iomeron 400 mg/mL; low mAs. Right Panel: Moderate flow rate (3.5mL/s) Iomeron 400 mg/mL) and high mAs). Constant kV.
The high flow/low mAs protocol enabled a reduction in radiation dose by 33% with a higher image quality and contrast-to-noise ratio

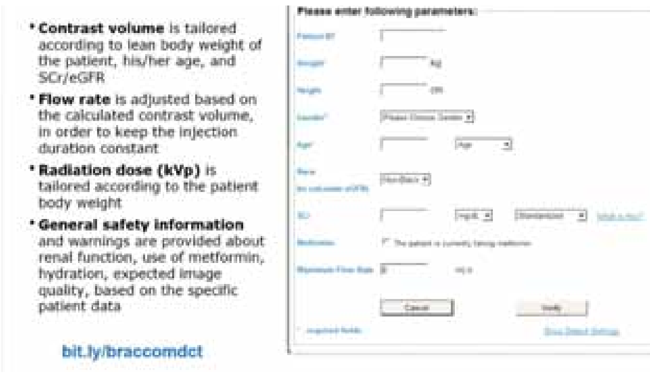

Figure 2. Optimization of the various parameters needed for individualized protocols is facilitated by use of software packages such as Bracco's DistinCTive web-based software. The software has been validated in multi-center trials which showed that tailored protocols yielded equivalent image quality as with standard protocols but at lower radiation dose and contrast usage

At lower kV the attenuation of iodine is increased but the lower number and energy of the photons means that also the noise is increased. If a constant signal-to-noise (SNR) ratio is maintained then the greater noise can be offset by the greater iodine signal. The value of HCCM in this context is that the greater signal relative to the increased noise can be used to reduce the mAs and thus the radiation dose. By maintaining a high iodine delivery rate (IDR), the peak enhancement is higher than that with lower concentration CM which means that greater noise can be accepted which in turn means that the mAs can be reduced.

Prof Bäuerle presented practical examples of the effect of varying scan parameters.

- High flow, low mAS protocol for CTA [Figure 1] A reduction of radiation dose of up to 33% can be obtained with higher image quality and contrast to noise ratio
- In another study of CTA used to monitor endovascular aortic repair after abdominal aneurysm, two protocols were compared. One used 90 mL of Iomeron 400 mg/mL at 80 kV and the other used 120 mL Iomeron 300 mg/mL at 120 kV. It was found that a radiation dose reduction of 74 % could be obtained with the low kV protocol without significantly affecting the contrast to noise ratio (CNR).

TAILORING PROTOCOLS

The existence of built-in automated tools for kV/mAs optimization on modern scanners makes tailoring protocols much easier. The availability of the web-based software package DistinCTive (Bracco; www.braccoMDCT.com) provides additional benefit to radiologists in permitting customization of CT protocols for individual patients. The system optimizes the contrast volume, flow rate, radiation dose (kV) and also takes into account patient-related factors such as renal insufficiency etc. [Figure 2].
The system has been validated in a multi-center trial involving 1493 patients undergoing MDCT examinations of the abdomen, liver chest or aorta using either Iomeron 400 or Iopamidol 370. The aim of the validation study was to compare a standard conventional protocol with individualized patient protocols as determined by the DistinCTive system. The results revealed equivalent diagnostic quality for both groups, but with significant reductions in both radiation dose and contrast media in the tailored group.

SUMMARY

- Greater radiation dose reductions are possible in low kV/mAs protocols with the use of HCCM
- Tailored protocols to suit individual patients are desirable. Automated tools and software solutions such as Bracco's DistinCTive system greatly facilitate individualization of protocols.
- The take-home message is that HCCM better permit greater reductions in radiation/contrast dose due to greater flexibility of administration.

Evolving technology, evolving needs: an integrated approach to patient management

Prof Riccardo Manfredi.

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The principal objectives of Prof Manfredi's presentation were to review the development of scanner technology and in the light of this, to discuss the benefits of high concentration contrast agents and the recent evolution of CT power injectors.

Evolution of CT scanner technology.

One consequence of the development of CT scanners from the original single slice spiral CT up to current 256, and 320 slice scanners and dual source MDCT systems is a reduction in scan time. This development has been accompanied by a dramatic rise in the number of CT exams being performed. Approximately 50% of all CT exams involve the administration of contrast medium.
The classical curve of enhancement on CM administration can be affected by several factors such as

- the scanner parameters, e.g. scan delay, duration, bolus tracking
- contrast medium parameters, e.g. injection rate/time, volume, concentration
- patient-related factors such as age weight, height, cardiac output etc.

All these factors combine to influence the contrast enhancement.
Regarding **contrast medium**, factors such as increased injection rate will mean that the peak enhancement curve is increased and moves to the left whereas the delayed enhancement remains basically unchanged [Figure 3].

Conversely, if the injection volume is increased, both the peak and delayed enhancement are increased. Another factor which affects the curve is the iodine concentration. Increasing the iodine concentration with a constant volume and injection rate results in greater enhancement but a higher amount of administered iodine. However, reducing the volume while maintaining the injection rate permits a tighter bolus and greater possibilities for contrast dose reduction.

Accompanying these developments in CT scanner technology and the advent of high iodine concentration contrast media, has been the evolution of CT power injectors, which are now critical components in the CT suite.

The two major needs to be met in CT are ensuring the uniform injection of contrast medium at the desired volume and rate while maintaining the overall expectations and diagnostic accuracy of the CT examination itself. The CT Exprès injector system from Bracco has been developed to meet these objectives. Designed for optimal safety and efficiency, the CT Exprès system is syringeless and can be operated to tailor contrast administration to individual patients/special protocols [Figure 4].

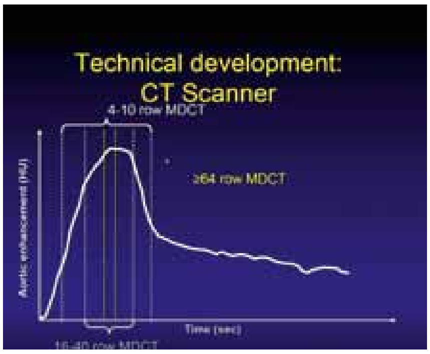

Figure 3. As the number of CT rows increases, the acquisition time can be reduced. With increasing iodine concentration of the contrast media, the bolus can be reduced

The system has been evaluated in a prospective study involving 275 patients in which the CT Exprès system was compared with a dual-syringe system. This study showed that CT Exprès led to a reduction of 65% in patient preparation time and a 75% reduction in the time-to-release of the patient after the procedure. Overall, an increase in patient throughput of 2.6 patients per day was achieved together with reduced CM wastage and increased technologist satisfaction.

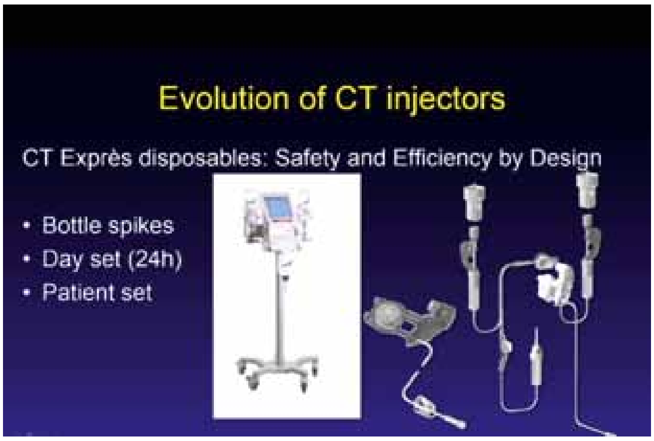

Figure 4. Designed for optimal infection control, safety and efficacy, the CT Exprès injector system from Bracco is syringeless and can be operated either with a day set which is of use in very busy CT suites or a patient set for use with individual patients

SUMMARY

- CT scanner technology has evolved considerably and rapidly.
- High concentration contrast media are beneficial in conjunction with more rapid scan times, enabling tighter boluses and increased opportunities for radiation dose saving.
- The development of syringeless power injectors such as CT Exprès brings considerable advantages.

Implementing ALARA with imminent Compliance Directives: dose optimization through monitoring

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Prof Vanzulli had three objectives in his presentation:

- to provide a simple practical and overview of the imminent EURATOM directive
- to describe practical implementation of the ALARA principle and the use of dose monitoring as a tool for optimization
- to share the experience of his team's use of the NEXO Dose system in the Niguarda Hospital in Milan

EURATOM DIRECTIVE

The directive (2013/59) is due for implementation in February 2018 and sets out the various responsibilities of the radiologist, technologist and the medical physicist in establishing, optimizing and maintaining protocols such that they deliver a dose that is As Low as Reasonably Achievable (ALARA). An additional stipulation of the directive is that the radiologist must explain the implications of the risk/benefits of the radiation dose to which the patient will be exposed.

The Directive requires that by the Feb 2018 deadline, written protocols for standard medical procedures should be established (and appropriately maintained and applied) for "relevant categories of patient". In addition, dosimetric indices from diagnostic procedures should be collated and entered into the patient records. Fortunately the directive recognizes that a "graded approach" to such regulatory control can be applied. Thus for example only newly installed hardware must have the dose reporting facility — and in fact all modern scanners already have the ability to store DLP and CTDI data.

It is still unclear as to what precisely should be entered in the records for dosimetric indices. Some experts recommend that hard data such as DLP should be recorded. Others consider that non-numerical information such as Exposure band classification based on Radiation Protection RP 118 guidelines should be included. These are easy to understand and avoid direct comparisons since no numerical data are cited, but this approach in not very informative and also somewhat outdated.

ALARA or ALADA?

Another debate is still on-going regarding the danger of overemphasis of the ALARA principle — it has been suggested that the "As Low as Diagnostically Acceptable " (ALADA) principle is more appropriate

Article 60 of the Directive requires that protocols be adequately tested and maintained; fortunately industry is already producing integrated Radiation Dose Index Monitoring (RDIM) systems which are extremely useful. RDIM systems are designed to :

- Collect radiation dose index (RDI) from the imaging modalities
- Store the RDI in a database together with patient demographics and study information
- enable easy visualization and analysis of the RDI data.

RDIM systems are however not databases for patient dose and patient organ dose. These involve complex calculations not just based on X-ray output, and are typically generated by medical physicists. Organ and effective doses should therefore not be included in the report.

Figure 5. IIn The Niguarda Hospital, Milan, the NEXO [Dose] system plays a central role in the process of designing, running, monitoring and optimizing of protocols'. The monitoring phase is particularly useful in that it can identify non-optimized protocols, reveal any scanner malfunctions or any misuse of procedures

PRACTICAL EXPERIENCE

The Radiation Dose and Monitoring system from Bracco is known as **NEXO [Dose]** and efficiently collects dosimetric data from PACS or from radiology devices. The data are stored in a web-based database from which the data can be exported for statistical analysis.

The Niguarda hospital has a long experience of the Nexo-Dose and has now accumulated more than 220 000 CT angio exams. The Nexo system permits information such as the number of patients that have received the most angio and/or CT exams over the previous year to be retrieved. Alternatively an overview can easily be retrieved of the dose associated with each type of exam, e.g. CT of the thorax, of the head, etc. over whatever given time period.

The rationale for the use of the NEXO [Dose] system in the Niguarda hospital is summarized in Figure 5, with the principal objective being the establishment of appropriate protocols. This involves initial definition of the procedure followed by a period during which the protocol is run in practice for a certain amount of time, after which the system allows monitoring of the associated doses which is then used for eventual updating of the protocol.

Niguarda has found that the monitoring phase is particularly useful in that it can identify non-optimized protocols, as well as reveal scanner malfunctions and any misuse of the procedures.

A typical example of the practical application of this process is shown in Figure 6, which demonstrates the dose associated with CT of the abdomen over time. It can be seen that after protocol optimization the dose data are lower and more homogeneous. Additional information that can be generated by the system includes a comparison of doses associated with various scanners throughout the institution, or for example a comparison of doses with scanners that use iterative reconstruction compared to those that utilize Filtered Back Projection. The system can also generate email alerts whenever a particular patient has been exposed to a radiation dose greater than the 95 % percentile of the mean radiation dose exposure. Niguarda received 131 such notifications over a 6 month period. The system enables analysis of the reasons behind the alerts and can differentiate cases in which the additional dose was due to uncontrollable factors such as patient obesity from technical errors such as miscentering or arm-lowering.

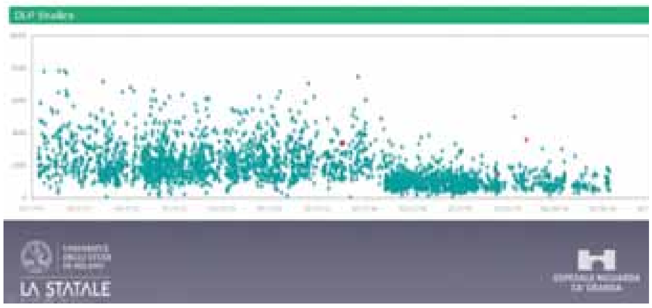

Figure 6. An example of the effect of use of the NEXO [Dose] system. The above figure shows the dose associated with CT of the abdomen over time. It can be seen that after protocol optimization the dose data are lower and more consistent

TAKE HOME POINTS

- Implementing ALARA to comply with the new (2013/59) directive which will be implemented in 2018 requires a multidisciplinary team, with medical physicists playing a central role
- Diagnostic images must be acquired using tested protocols optimized for radiation dose for each type of examination
- Accurate radiation dose values must be recorded for diagnostic procedures
- The NEXO [Dose] system is extremely useful for such CT protocol optimization and monitoring