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A Technique for Determining Pump Injector Settings for an On-Table CT or 3D DSA in Interventional Radiology

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Abstract

INTRODUCTION: On-Table computed tomography (CT) or 3D digital subtraction angiography (DSA) in interventional radiology (IR) has become a valuable diagnostic tool.

METHODS: A review of the literature found a poor evidential base supporting the technical parameters for iodinated contrast delivery during these acquisition sequences.

RESULTS AND CONCLUSION: This technical note presents an easy method of estimating the parameters needed to reliably obtain diagnostic on-table CT or 3D DSA images, whilst attempting minimising contrast dose.

IMPLICATIONS FOR PRACTICE: A systematic approach to estimating contrast delivery regimes during on-table CT and 3D DSA can help ensure diagnostic quality images are obtained. Further clinical studies are now required to rigorously evaluate this protocol.

Introduction

Since its introduction in the late 1990s[1] the use of 'on-table' 3D volume acquisitions during interventional radiology (IR) procedures has become standard practice in many hospitals. Typical IR volume acquisitions may be either on-table computed tomography (CT) scans or three-dimensional digital subtraction angiograms (3D DSA). Both techniques are generated by rotating the C-arm around the patient during image acquisition and then reconstructing the data into a useable format[2]. Several fluoroscopy equipment manufacturers now produce at least one unit capable of producing 3D images[3-6].

During IR, if an on-table CT examination using iodinated contrast is required, or a 3D DSA acquisition, then it is necessary to inject the patient with contrast before and during the acquisition to delineate the structures of interest. These injections are performed using a pump injector, which is pre-programmed prior to the acquisition to deliver the correct amount of contrast, at the correct time and at the correct rate. The use of iodinated contrast agents has long been associated with potential renal injury[7] and it is therefore desirable to keep the contrast volume as low as possible without sacrificing image quality[8]. Intra-arterial contrast agent delivery protocols must also consider the risk of intimal arterial trauma and thus carefully consider both the flow rate and maximum pump pressure. For the remainder of this technical note the contrast injection regime will refer equally to both on-table CT and 3D DSA procedures.

A review of the published literature highlighted that there were no published techniques for optimising contrast delivery specifically during on-table CT or 3D DSA procedures. A brief review of the literature was performed using the NHS National Institute for Health and Care Excellence (NICE) Healthcare Databases Advanced Search system; databases searched were Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed and Science Direct, as well as a keyword search of Google Scholar. The aim of this technical note is to offer a description of a current contrast delivery protocol in use at a single centre and aims to promote discussion and debate about the best practice in on-table CT and 3D DSA procedures. In addition to the technical note a series of case studies are provided as examples of how the contrast delivery protocol can be used.

Methods

In light of a lack of literature to guide practice in this relatively new field, contrast injection protocols in the study centre were not standardised. Following review by the clinical team, a new model for calculating contrast delivery parameters was implemented. As with routine clinical care protocol amendments are common and this was subsequently considered to be service improvement and therefore did not require ethical approval.

Theoretical basis

To provide adequate opacification of vessels for an on-table CT angiogram or 3D DSA it is necessary to determine a number of parameters. For the purposes of this work adequate opacification refers to clinically acceptable filling and density of the desired vessels. Parameters to be selected include 1) the desired or target contrast density and 2) the three parameters which are set on the pump injector:

- ***r*** = the flow rate of the injection (mL/sec).
- ***v*** = the total volume of contrast to be injected (mL).
- ***X*** = the time delay between initiating the contrast injection and the start of the X-ray acquisition (sec).

Such values can be empirically derived from two other known values:

- ***d*** = the cross-sectional diameter of the vessel intended for opacification (mm).
- ***t*** = the total acquisition time (sec).

Within our practice, the flow rate (***r***) is estimated using the diameter of the target vessel (***d***). By way of an example, for a 6 mm vessel a good starting point is a flow rate of 6 mL/sec and for a 2 mm vessel we would initially select 2 mL/sec. It is at the clinicians' discretion to adjust this value to account for specific patient-specific variations in anatomy or physiology (e.g. slow flow in a diseased vessel, or faster flow in a fistularised vein).

$$r = |d|$$

The acquisition time delay (***X***) is the time required to pre-opacify the structure in order to acquire the high-quality images; this is again at the clinicians' discretion. A delay of between two or three seconds is likely to be enough for most arterial structures, longer would be required to provide portal-venous filling and this would also depend on the presence of pathology, for example varices.

The volume of contrast to inject (***v***) is the amount of contrast required to opacify the vessel for the duration of the acquisition (***t***). To gain the high-quality images, it is necessary to pre-fill the vessel before the acquisition begins; this is achieved by applying an acquisition delay to a synchronised injector pump (***X***).

$$v = r\,(t + X)$$

Contrast Density

Using an iterative method prior to writing this technical note, it was found that a 2:1 (saline to contrast agent) mixture ratio provided good opacification of all structures, without streak artefact. Following on from our initial work, this saline to contrast agent ratio has been adopted as the standard approach for all 3D (DSA and on-table CT) acquisitions within our institution.

Contrast Administration Technique

Using the contrast administration protocol described above, to date 25 3D volume acquisitions have been performed on an Artis Zee (Siemens; Munich, Germany). The contrast used was Visipaque 270 (GE Healthcare; Oslo, Norway), injected with an Angiomat Illumina pump-injector (Guerbert Group; Villepinte, France).

Following implementation of this new model, 3D DSA or on-table CT studies from 25 patients were prospectively evaluated by a consultant interventional radiologist with 18 years' of experience in interventional radiology. Procedures in which the volume acquisitions were acquired included: trans-arterial chemo-embolisation (TACE), prostate artery embolisation (PAE), mesenteric angiography and portal vein embolisation.

Results

All volumes acquired provided adequate levels of opacification without any significant streak artefact, whilst attempting minimising contrast burden.

Discussion

To the authors' knowledge there is no published literature on injector protocols for 3D vascular interventional acquisitions. The formula and guidance described in this report provides a starting point for the calculation of the parameters required to acquire diagnostic on-table volumes during IR procedures. It is accepted that other methods might be suitable, and that further comparisons and clinical studies are required. A number of limitations in our work exist; the quality of the images was subjectively appraised by a single consultant radiologist without any formal scoring tool. We have not performed any formal comparisons of image quality and contrast dose before or after the implementation of this protocol. Such a retrospective comparison would be problematic in that some essential parameters would not have been collected.

Conclusion

The technique described provides an easy method of estimating the parameters needed to reliably obtain diagnostic images, whilst attempting minimising contrast dose, during IR procedures. Clinical studies are needed to further refine and evaluate contrast delivery regimens.

Conflicts of Interest

No conflicts.

Appendix

Example 1 – 3D CT hepatic angiogram

To perform a 3D CT angiogram of the hepatic arteries from which the operator estimates the vessel diameter to be 6 mm using prior imaging / an initial angiogram:

Using $\boldsymbol{r = |d|}$

Gives $\boldsymbol{r = |6\ mm| = 6}$

Meaning the flow rate can be taken to be **6 mL/sec**.

The 3D CT acquisition is 6 seconds duration (***t***), and based previous angiograms and experience the operator estimates that it will take 3 seconds (***X***) to pre-opacify the vessels:

Using $\boldsymbol{v = r\,(t + X)}$

Gives $\boldsymbol{v = 6\,(6 + 3) = 54\ mL}$

Using this information, the settings that can be entered into the pump injector are:

- Volume = 54 mL
- Flow rate = 6mL/sec
- Acquisition delay = 3 secs

Worked Example 2 – 3D DSA of the prostatic arteries

To perform a 3D DSA of the prostatic arteries from which the operator estimates the vessel diameter to be 3 mm using prior imaging / an initial angiogram:

Using $\boldsymbol{r = |d|}$

Gives $\boldsymbol{r = |3\ mm| = 3}$

Meaning the flow rate can be taken to be **3 mL/sec**.

The acquisition protocol on the angiography unit requires a 5 second mask acquisition, followed by a 'return' movement, and then a 5 second DSA acquisition (***t***). Communication with the pump injector occurs at the point of 'return' and it is from this point that the delay is applied. The operator estimates, based on prior imaging and experience, that it will take 2 seconds (***X***) to pre-opacify the vessels.

Using $\boldsymbol{v = r\,(t + X)}$

Gives $\boldsymbol{v = 3(5 + 2) = 21\ mL}$

Using this information, the settings to be entered into the pump injector are:

- Volume = 21 mL
- Flow rate = 3mL/sec
- Acquisition delay = 2 sec

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