Timing of portovenous (hepatic) phase abdominal CT

RAD Magazine, 45, 524, 19-20

Matthew Benbow
Superintendent radiographer
Dr Nik Hennessy
Consultant radiologist
Carlo Vitale
Senior radiographer
Royal Bournemouth Hospital, Dorset
matthew.benbow@rbch.nhs.uk

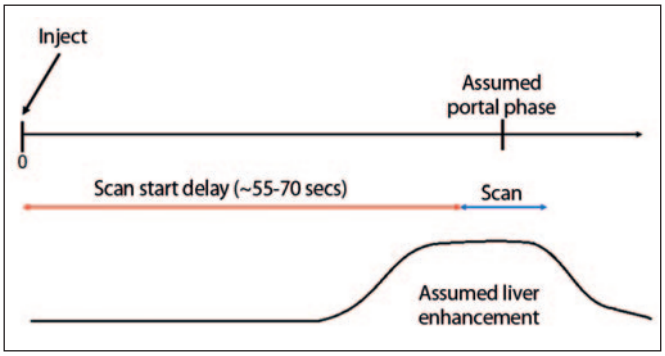

Figure 1
Fixed delay.

Introduction

While abdominal CT can be performed at a range of differing intravenous contrast phases, rarely is the portal venous (hepatic) phase omitted.[1] During a recent period at our DGH department, 38% of all patients referred for CT scanning received a portovenous phase abdominal scan, making it one of the most common scans performed.[2]

The aim is for the contrast media to be given sufficient time following a peripheral venous injection (usually in the arm) to optimally enhance the liver parenchyma and thereby maximise contrast between normal and abnormal liver tissue. The majority of the blood supply to the liver comes from the portal vein and so the contrast travels from the injected vein to the superior vena cava, right atrium, right ventricle, pulmonary arteries, pulmonary capillaries, pulmonary veins, left atrium, left ventricle, aorta, visceral organs (including mesentery, spleen, stomach and pancreas), portal vein and finally the liver parenchyma. It therefore takes time for the liver parenchyma to become loaded with contrast so an appropriate start delay for scanning after the injection must be added. Scanning too early or too late would result in sub-optimal enhancement and reduced diagnostic confidence. We would of course like to achieve perfect enhancement every time for all patients, but there are factors, some more controllable than others, that make this not always simple.

Timing options

Achieving a suitable contrast media delay can be performed in several ways, each having its own benefits and problems. One of the most common methods is using a **fixed delay** technique. Here, the injection of contrast media and a fixed countdown for a delayed scan start are simultaneously initiated (**figure 1**). The delay used varies between centres, but it is commonly set between 55 and 75 seconds. The benefit of this technique is that it is simple and robust to perform. It also allows the radiographer time to safely stay in the scan room to check that no extravasation of contrast occurs during the injection. The downside, however, is that the delay used relies on an assumption that it is optimal for all patients and by that very nature is inaccurate. If the ideal liver parenchymal enhancement is earlier or later than the added delay, then the scan will be performed too late or too early respectively and the images will be sub-optimal.

An alternative method can be to perform a **timing scan**. Here, a lesser volume of contrast media is first injected and a stopwatch (that may be part of the scanner software) started simultaneously. After a delay of around 40 seconds, intermittent single-slice images are obtained through the liver until the parenchymal enhancement begins to fade.

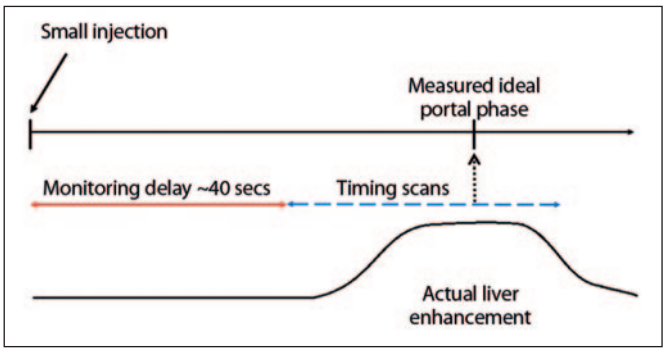

Figure 2
Timing scan.

The images are reviewed and the delay time of the image displaying the best enhancement can then be used to perform the main scan with the full contrast dose (**figure 2**). This is an improvement over using a fixed delay, in that the timing is measured and should therefore be correct; however it is a little more time-consuming and so less often used in practice. Also, it requires 15 to 20ml of contrast media for the test bolus, which will still be in the patient's system for the subsequent diagnostic scan and therefore could affect interpretation of the images.

A further approach is to use **bolus triggering**, and there are options of how to do this. It can be performed using region(s) of interest over the liver parenchyma to establish optimum enhancement. However, an ideal attenuation (Hounsfield unit) to trigger the scan is difficult to decide upon as it will be affected by liver pathologies such as fatty liver or haemochromatosis and systemic factors such as poor cardiac output or sepsis. Even optimal timing in such patients may actually only offer relatively poor enhancement and so may never reach a specified trigger threshold.

Probably the most common timing method is to use the aorta alone to bolus-trigger, followed by a fixed delay of around 45 seconds before starting the scan. This method accommodates differences in cardiac output. Patients with a hyperdynamic circulation will trigger early and therefore receive an earlier portal phase scan than those who trigger later (**figure 3**).

This method has been used at our centre for around 15 years and, while it takes into account differing cardiac outputs, we still felt that it was not perfect and could be improved upon.

Hypothesis

Our hypothesis was that patients who trigger early may benefit from an even shorter delay than we routinely add and their liver parenchyma may enhance optimally before the fixed delay of 45 seconds. Even more strongly we felt that patients who trigger late have a hypodynamic circulation and liver parenchymal enhancement may improve if the delay was longer than 45 seconds. Could a flexible added delay, as a function of the time taken for the initial trigger, improve portal venous phase timing?

Study

For 86 patients undergoing portovenous phase CT abdomen scanning using an aortic bolus trigger + 45 seconds technique, we asked the radiographers to record the time from injection start to bolus trigger. We then asked an experienced radiologist to review the cases and score them as to whether the scan was performed too early, optimally or too late.

A pre-contrast study was not acquired and therefore it was not possible to account for variations in liver parenchymal attenuation, such as reduced attenuation in fatty liver disease or increased attenuation in haemochromatosis. Additionally, in acutely unwell patients the blood supply to less essential organs including the liver is decreased and so optimal liver parenchymal enhancement may never be achieved. Therefore an absolute value of liver parenchymal attenuation was not felt to be a reproducible method of assessing the timing of the CT. Instead, the relative attenuation within the lumen of the aorta, portal vein and inferior vena cava (IVC) below the level of the renal veins was used. When the attenuation in the aorta was greater than in the portal vein, this indicated the scan was too early. When the portal vein attenuation exceeded that seen in the aorta, combined with possible laminar flow in the IVC above the renal veins and no contrast in the IVC below this level, this was deemed optimal. If the aorta, portal vein and IVC below the renal veins were all isodense, then this was considered to be too late.

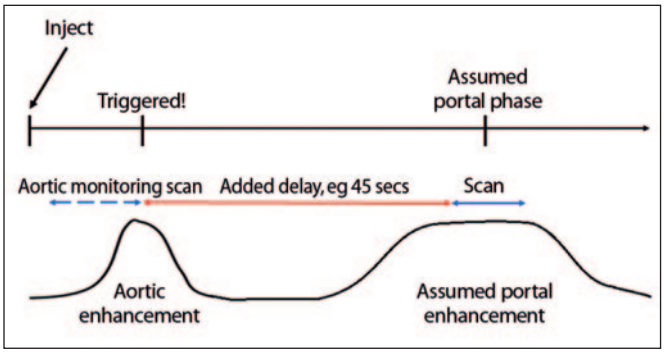

Figure 3
Aortic bolus triggering.

Variables

Before testing the hypothesis it was important that we recognised the other variables that always exist and try to minimise their effects as much as possible. **Figure 4** lists these variables alongside measures put in place to try to reduce the influence of each.

Most of the technical variables, such as contrast type, cannula size/position and bolus triggering settings could easily be standardised such that their effects on timing variations could be discounted. To ensure a consistent degree of enhancement despite differences in patient size, weight-based contrast protocols were used. These have been shown to offer more consistent enhancement between patients of differing sizes when compared to giving the same dose to all patients regardless of size.[3-5] For lighter patients, the injection rate was slowed in an attempt to keep the total injection delivery time for all patients similar, regardless of weight.

No adjustments could be reasonably made regarding the patient's individual fat/muscle content, liver size, liver

	Variable	Control measure for study
Technical variables	Contrast media strength	Use only one strength (370)
	Volume of contrast media used	Adjusted with respect to patient weight
	Injection duration/flow rate	Flow rates slower for lower contrast media volumes to attempt to keep injection duration fairly constant
	Saline chase or not	All saline chased
	Bolus trigger position	In aorta, upper abdo for all
	Bolus trigger threshold	150HU for all
	Cannula gauge	20G or larger used, ie no flow restrictions
	Cannula position	Anterior cubital fossa only
	kVp used	100kVp where possible 120 if needed for larger patients, but then contrast volume increased by 10ml to compensate for contrast reduction
	Beam filtration	Same for all used scanners
Patient variables	Patient weight	Weight-based contrast dosing used
	Poor renal function limitations	Excluded – all given desired contrast dose
	Ill (shocked) patients	Looked at in and outpatient groups separately
	Patient fat vs muscle	No adjustments made
	Liver size	No adjustments made
	Liver pathology	No adjustments made
	Cardiac output/circulation	No adjustments made

FIGURE 4
Variables to consider and understand that affect portal-venous phase enhancement.

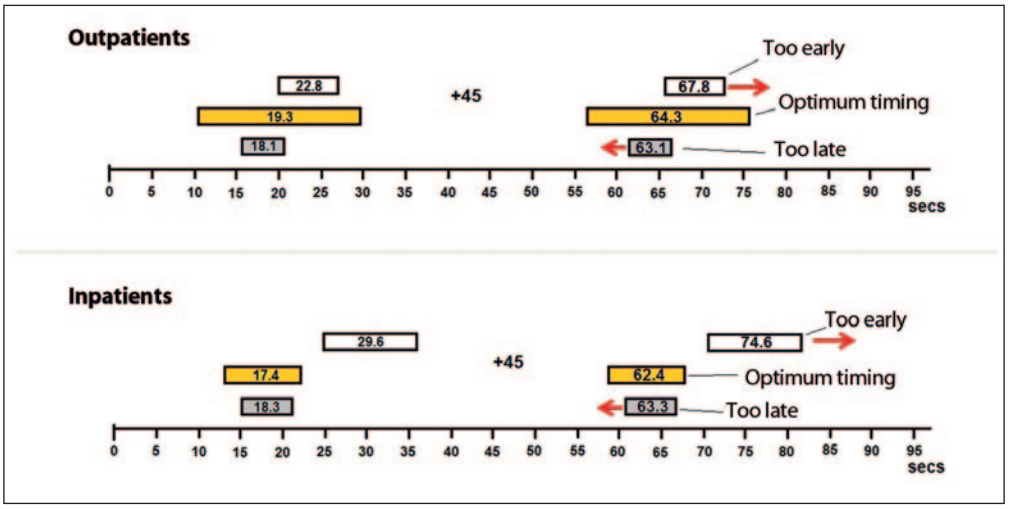

FIGURE 5
Results.

pathology, as these are generally unknown prior to scanning. Variations in cardiac output were also unknown in advance, but this was the main factor that we wanted to address in our attempt to improve portovenous phase timing across all patient groups.

Results and discussion

The study group included both inpatients and outpatients but these were analysed separately as it was felt that the cohort of inpatients were more likely to have patients with a hypodynamic circulation due to being acutely unwell. **Figure 5** shows the tabulated results of these two groups.

For each inpatient and outpatient cohort, the examinations that were deemed as being performed too early are shown in white, optimum timed examinations in yellow, and those considered too late are in grey.

The blocks to the left length represent the range of trigger times with the mean trigger time noted in each. The blocks to the right have then been positioned 45 seconds later and show the range and mean of total time post-trigger that the scans occurred.

For the outpatients, the mean time for aortic bolus trigger to occur was 22.8 seconds (mean scan time 67.8 seconds) for the group where the timing was considered to have been too early, 19.3 seconds (mean scan time 64.3 seconds) for the group considered to show optimal timing and 18.1 seconds (mean scan time 63.1 seconds) for the group considered to have been scanned too late. This suggests that those patients who triggered early would have benefited from a delay of less than 45 seconds and those patients who triggered late would have benefited from a delay of more than 45 seconds. However, it must be stressed that the study group was small and there was overlap between the three groups.

For the inpatients, the mean time for aortic bolus trigger to occur was 29.5 seconds (mean scan time 74.6 seconds) for the group where the timing was considered to have been too early, 17.4 seconds (mean scan time 62.4) for the group considered to show optimal timing and 18.3 seconds (mean scan time 63.3 seconds) for the group considered to have been scanned too late. While there was no discernible difference between the latter two groups, the patients who were scanned too early were those who required a longer time to trigger (mean 29.6 secs, range 25-36 secs). Although this group were scanned later (range 70-81 secs) they may have benefitted from an even longer delay before their scan. Again we must remember the study is small, but it does seem to support our hypothesis, particularly in the acutely unwell patients.

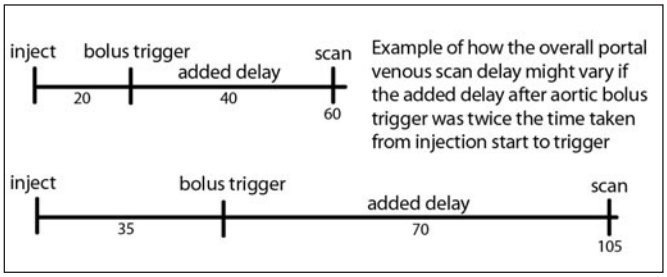

Figure 6
'Added delay = 2 x aortic trigger' example.

There is not yet enough evidence from this study to make changes to how we time our portovenous phase CT imaging but it does support the need for a larger study. If it can be shown that these findings are consistently correct then a formula could be devised that would tailor the delay to the patient thus optimising the liver parenchymal opacification in the portovenous phase, depending on their time to initially bolus trigger. This may be as simple as 'added delay = 2 x aortic trigger' (**figure 6**). This scenario would result in an overall scan start time of 60 seconds for a patient who triggered after 20 seconds (added delay = 40 further secs) or an overall scan start time of 100 seconds for a patient who triggered after 35 seconds (added delay = 70 further seconds).

If this could be proven, it would then require scanner manufacturers to create software that makes a flexible delay added 'on the fly' to the scan delay as soon as the aortic trigger time had been measured.

References

1, *Taylor C R, Mathur M. Abdominal Computed Tomography Scanning Technique. Medscape Website, Sep 2017.*
2, *RIS data from the Royal Bournemouth Hospital. January to March 2018 inclusive.*
3, *Benbow M, Bull R K. Simple weight-based contrast dosing for standardization of portal phase CT liver enhancement. Clin Radiol 2011;66(10): 940-44*
4, *Perrin E, Jackson M, Grant R et al. Weight-adapted iodinated contrast media administration in abdomino-pelvic CT: Can image quality be maintained? Radiography 2018;24(1):22-27.*
5, *George A J, Manghat N E, Hamilton M C K. Comparison between a fixed-dose contrast protocol and a weight-based contrast dosing protocol in abdominal CT. Clin Radiol 2016;71(12):1314.e1-1314.e9.*