Optimising Paediatric Trauma and Split-Bolus Contrast-Enhanced CT Examinations

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Introduction and Background

Contrast enhanced (CE) CT is vital for evaluating injuries and abnormalities. Tissue enhancement is visualised through the multi-phases of blood flow (arterial, parenchymal, portal-venous and venous). A split-bolus of contrast (2 volumes of iodine based X-ray dye) is pumped and scans performed to 'catch' contrast as it travels through the body using a multi-slice CT scanner (MSCT). However patients may be scanned twice to highlight correct phases, exposing them to double the radiation. This is a significant concern in paediatric scanning as children are more vulnerable to radiation effects[1]. Using a different technique we could scan a region of interest (ROI) once and still achieve dual/triple-phase enhancement[2]. As a CT radiographer working in a children's hospital I sought to develop a more appropriate protocol.

Camp Bastion Protocol (CBP) - currently promoted for all ages

CBP[3, 4] aids diagnosis of acute adult blast injuries, image quality is acceptable for battlefield scanning and the ROI is scanned once. But, contrast volumes, flow rates and ROI's scanned do not maximise parameters required for quality paediatric scanning. However, the protocol is routinely promoted for dynamic enhancement for all ages and a weight based contrast 'wheel' (figure 1) is used. CT scan commences at 70 sec. from initial injection, irrespective of individual arterial/venous flow rates.

Camp Bastion Contrast Calculator Wheel
Biphasic Injection Protocol in Trauma CT

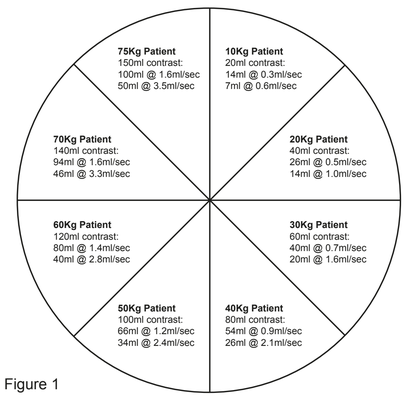

Figure 1

Scan protocol:

2/3 contrast volume injected at slow rate x, and 1/3 volume injected at approximately 2x. Contrast rates are calculated for injection phase to last 70 secs. Scan initiated at 70 seconds.

Pitfalls of CBP for Paediatric Imaging

Blood circulation times vary (for children, 20-25 sec. arterial, and 45-65 sec. venous), so scanning at 70 sec. may be too late. Density of iodine at low flow rates also means minimum enhancement. CBP, though, is of benefit in departments that only have a single headed injector. For general and especially dedicated paediatric departments, with a dual headed system, this protocol is suboptimal for image quality and ROI's scanned. Children are subjected to an examination which, in the vast majority of cases, is inappropriate and substandard. It does not fully compensate for increased blood flow rates or utilise best scanning parameters.

New Method for Paediatric CE Imaging - RHSC Trauma/Split-Bolus Protocol

Best enhancement is achieved if patient weight and appropriate flow rates[5] are considered along with scanning parameters. Consequently a CT protocol (image 1), data tables (tables 1 & 2) and pre-set pump parameters (image 2) have been devised. Now pre-calculated specific contrast volumes and scan initiation times are available. These reflect more accurately the expected arterial or venous enhancement times (images 3, 4 & 5).

RHSC Contrast Calculator Table - Delay Times & Flow Rates According to Weight for Trauma/Split-Bolus Enhancement

Weight of Patient	Total volume of contrast 2mls/kg	Flow rate/sec	1st contrast bolus volume (total volume halved)	Pause Time	2nd contrast bolus volume	Time into saline flush when CT scan started	Time to start CT scan
5kg	10mls	1.5mls/sec	5mls	24sec	5mls	17sec	**47sec**
10kg	20mls	1.5mls/sec	10mls	26sec	10mls	14sec	**52sec**
10kg	20mls	2mls/sec	10mls	35sec	10mls	15sec	**60sec**
15kg	30mls	2mls/sec	15mls	25sec	15mls	18sec	**57sec**
20kg	40mls	2mls/sec	20mls	30sec	20mls	15sec	**65sec**
25kg	50mls	2mls/sec	25mls	30sec	25mls	8sec	**62sec**
30kg	60mls	2mls/sec	30mls	25sec	30mls	10sec	**65sec**
35kg	70mls	2mls/sec	35mls	22.5sec	35mls	8sec	**64.5sec**
40kg	80mls	2mls/sec	40mls	20sec	40mls	5sec	**65sec**
50kg	100mls	2.5mls/sec	50mls	20sec	50mls	5sec	**65sec**
60kg	100mls	3mls/sec	50mls	23sec	50mls	8sec	**65sec**

Table 1

Working out of Delay Times & Flow Rates for Trauma/ Split-Bolus Enhancement

Weight of Patient	Total volume of contrast 2mls/kg	Flow rate/sec	1st contrast bolus volume (total volume halved)	Time of 1st bolus injection at flow rate chosen (A)	Pause Time (B)	Cumulative time of A + B	2nd contrast bolus volume (C)	Time of 2nd bolus injection (D)	Total time of both contrast injections + pause time A + B + D	Time into saline flush when CT scan started (E)	Time of arterial phase (2nd bolus + flush) D + E	Time of venous phase (1st bolus + pause + 2nd bolus + flush) A + B + D + E
5kg	10mls	1.5mls/sec	5mls	3sec	24sec	27sec	5mls	3sec	30sec	17sec	20sec	47sec
10kg	20mls	1.5mls/sec	10mls	6sec	26sec	32sec	10mls	6sec	38sec	14sec	20sec	52sec
10kg	20mls	2mls/sec	10mls	5sec	35sec	40sec	10mls	5sec	45sec	15sec	20sec	60sec
15kg	30mls	2mls/sec	15mls	7sec	25sec	32sec	15mls	7sec	39sec	18sec	25sec	57sec
20kg	40mls	2mls/sec	20mls	10sec	30sec	40sec	20mls	10sec	50sec	15sec	25sec	65sec
25kg	50mls	2mls/sec	25mls	12sec	30sec	42sec	25mls	12sec	54sec	8sec	20sec	62sec
30kg	60mls	2mls/sec	30mls	15sec	25sec	40sec	30mls	15sec	55sec	10sec	25sec	65sec
35kg	70mls	2mls/sec	35mls	17sec	22.5sec	39.5sec	35mls	17sec	56.5sec	8sec	25sec	64.5sec
40kg	80mls	2mls/sec	40mls	20sec	20sec	40sec	40mls	20sec	60sec	5sec	25sec	65sec
50kg	100mls	2.5mls/sec	50mls	20sec	20sec	40sec	50mls	20sec	60sec	5sec	25sec	65sec
60kg	100mls	3mls/sec	50mls	17sec	23sec	40sec	50mls	17sec	57sec	8sec	25sec	65sec

Table 2

Pre-Programmed Trauma Protocol on CT Console

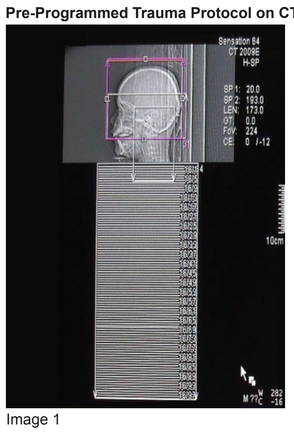

Image 1

Pre-Programmed Pump Programme

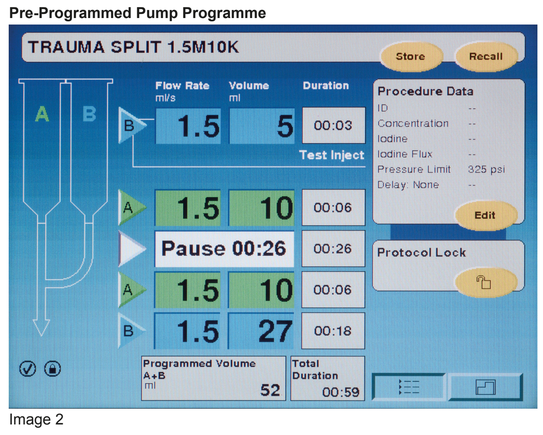

Image 2

Arterial & Venous Enhancement Displayed Using the Split-Bolus Protocol

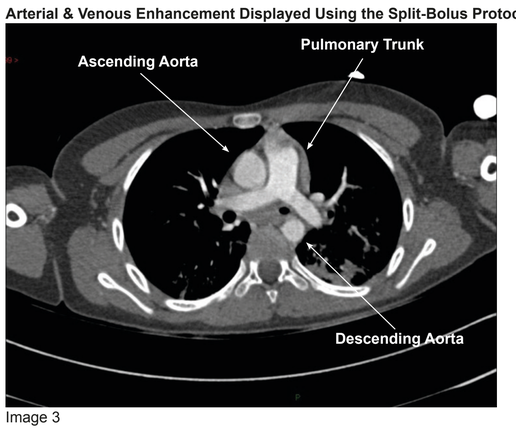

Image 3

Arterial & Venous Enhancement Displayed Using the Split-Bolus Protocol

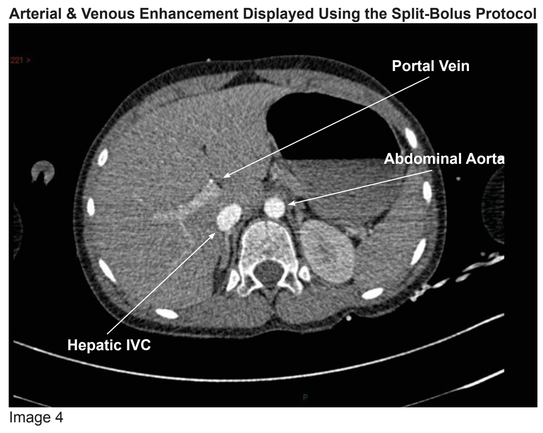

Image 4

Dual Phase Enhancement for Liver Mass using Split-Bolus Protocol

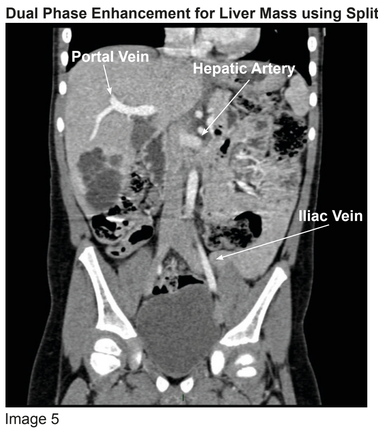

Image 5

Training

Training material has been devised to improve scanning confidence in performing a complex examination in often stressful circumstances, complemented by use of a test 'phantom' and multi-use syringes (image 6).

Conclusion

A more appropriate alternative to the CBP can be performed by utilising accurate circulation times. Pre-programmed CT protocols and pump factors ensure appropriate ROI's and scanning parameters are used, maximising image quality and facilitating best practice for all ages but particularly for paediatric patients. The increased contrast density improves enhancement and diagnosis[5, 6]. An added bonus is that contrast is not wasted on patients under certain weights. RHSC technique can be used on any MSCT scanner and the table data can be pre-programmed into any dual-headed syringe pump console (image 7) maximising their capabilities.

Image 6

Image 7

References

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