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Improved CT Contrast Injection Rates through Implantable Chest Power Ports

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Abstract

Objective: To optimize chest port contrast injections using step-wise improvements.

Methods: Ex-vivo injections were tested. 200 scans using power port injections were then evaluated.

Results: The highest flow rate was achieved using a 19G access needle, larger diameter tubing, and warmed contrast.

The mean injection rates in baseline and post-improvement groups were 2.7 ± 0.4 mL/s and 4.8 ± 0.4 mL/s, respectively ($P < 0.0001$).

Conclusion: Component optimization of the port apparatus can maximize contrast flow rates.

Keywords

port; contrast; CT; injection; rate

Introduction

Computed tomography (CT) examinations that require robust enhancement and timing such as for liver imaging require an optimal intravenous (IV) injection technique [1]. Arterial and late arterial phase imaging is often performed at contrast injection rates of 4–5 mL/s given the improved enhancement as rates increase [2]. The higher injection rates require larger gauge IV catheters that are preferably placed in an antecubital fossa vein to allow for the higher associated pressures during injection. However, when a patient has a power port device, concerns over IV placement are alleviated.

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While power ports allow for a central catheter injection, which alleviates concerns regarding repeat IV placement discomfort and extravasation risk, key considerations should be made to optimize port injections. In contrast to short, peripheral IV catheters, a power port injection requires the proper placement of an access needle into the port hub and then utilizes a long tubing connection to the injector, both of which can vary in diameter and length. In our high volume practice, prior to this study, we frequently encountered pressure-limiting injections that resulted in contrast flow rates significantly below the 5 mL/s for which the power ports are rated. For high injection rate examinations, this required placement of a peripheral IV, which resulted in patient discomfort and decreased efficiency of operations.

In this study, we evaluated our current port injection practice and carried out step-wise changes to our port apparatus to improve flow rates ex-vivo followed by comparison of patient scans before and after the changes.

Materials and Methods

This retrospective study was approved by our institutional review board as Health Insurance Portability and Accountability Act compliant, and the need for informed consent was waived.

Ex-vivo testing

Step-wise evaluation of our port injection apparatus was carried out utilizing the available components at our institution. A MedRad dual syringe injector (Bayer Healthcare, Whippany, NJ) was tested through two different inner diameter sizes of 60 cm length tubing: our baseline 1.524 mm single lumen inner diameter tubing (LPDCT-160, Bayer Healthcare) and a larger 1.77 mm single lumen inner diameter tubing (C405-0060, Coeur, Washington, NC). A neutral displacement connector (MC100 MicroClave Clear, ICU Medical, Inc., San Clemente, CA) was used to connect the port access needle tubing to the low pressure connector tubing. Three available vendor access needle packs were tested: our baseline 20 G pack (Gripper Plus Power P.A.C., Smiths Medical ASD, Inc., St. Paul, MN) and a second vendor pack in both 20 G and 19 G (Power Loc Max, Bard Access Systems, Inc., Salt Lake City, UT). The components were used with our most common 6 Fr polyurethane power port (Bard Access Systems, Inc.) for subsequent ex-vivo testing. Lastly, separate injections were made using room temperature and 37° C warmed contrast.

Injection rates were begun at 3mL/s and the rate was increased incrementally until the injector pressure limit of 300 psi was reached; once the pressure-limiting feature was triggered, one part of the injector set-up was changed, and then retested.

Patient scan evaluation

200 oncology outpatients and their injection data were evaluated: 100 baseline scans prior to (6/2014–1/2015) and 100 scans after (10/2017–5/2018) the port injection apparatus process improvement using combination 4 (Figure 1). Only scans with contrast injection through a power port in the chest (5 mL/s and 300 psi rating) and from protocols using 150 mL of Iohexol (Omnipaque 350; General Electric, Shanghai, China) were included.

Patient age, sex, programmed contrast flow rate, actual contrast flow rate, peak injection system pressure, and flow-limiting injection status were recorded.

Statistical Analysis

Patient age summarized using mean, standard deviation (SD), minimum, and maximum. Mean comparison of injection rates and pressures was performed using paired *t*-test. Tests were 2-sided, and P-values of 0.05 or less were considered statistically significant.

Results

Ex vivo testing

The tested apparatus combinations with maximum achieved actual contrast injection rates without pressure limitation and peak pressures are shown in Figure 1.

Patient scan evaluation

The baseline (33 men, 67 women) and post-process improvement patient groups (41 men, 59 women) had a mean respective age $\pm$ SD of 58 ± 12 years (range 20–88 years) and 58 ± 12 years (range 18–80 years); the baseline programmed rate of injection was 2.8 ± 0.5 mL/s (range 2–5 mL/s) and after process improvement, the programmed rate of injection was 5.0 ± 0.0 mL/s (range 4.9–5 mL/s). The mean actual contrast injection rate and peak pressure in the baseline patient group were 2.7 ± 0.4 mL/s (range 1.2–3.4 mL/s) and 261 ± 43 psi (range 132–332 psi), and the values in the post-improvement patient group were 4.8 ± 0.4 mL/s (range 2.3–5.4 mL/s) and 263 ± 29 psi (range 201–332 psi). The mean difference of actual injection rates between groups was 2.1 mL/s (95% confidence interval (CI), 2.0–2.2) ($P < 0.0001$) and the mean difference of peak pressures was 2.8 psi (95% CI, -7.21 – 12.75) ($P = 0.5829$) (Figure 2). Despite significantly higher injections rates, the post-improvement group only had 12% of injections with pressure limitation at a 300 psi threshold compared with 19% in the baseline group.

Discussion

This study demonstrates a common contrast injection issue and practical solution for CT departments to optimize injections through power ports for which there is scant information in the literature that often pertains to non-tunneled central venous catheters or lacks details such as injection rate information [3–5]. Our study reveals the importance of assessing the entire port injection apparatus. Prior to this evaluation, it was common in our practice to place a peripheral IV catheter to allow for high contrast injection rates of 4 – 5 mL/s for certain protocols. This process had arisen from previous attempts to use power ports at high rates, which often resulted in pressure-limiting injections at a 300 psi threshold, thus precluding optimal contrast rates for examinations such as pulmonary embolism chest CT, liver, and pancreas protocols. The few published studies on power port injections show that other institutions are also injecting contrast at suboptimal rates [5–7].

We evaluated the port injection components used at our institution and found that there were larger diameter options for the injection tubing and gauges for the access needles. Ex-vivo

testing showed that using the larger diameter tubing and a 19 G needles could improve our injections rates up to 4.2 mL/s. Furthermore, by then using warmed contrast, delivered rates could reach 5 mL/s without pressure limitation given the resultant decrease in viscosity [8]. After this new process was implemented, all of our protocols can now be performed using power ports (Figure 3). This new process has improved our CT department efficiency and removed the discomfort experienced by patients related to peripheral IV placement. Fewer suboptimal injections now occur during port injections, thus improving image quality, with the greatest improvement identified on arterial phase imaging [2].

There are limitations to this study. First, the findings are vendor-specific and the study only assessed one type of contrast media. However, our findings should be generalizable such that any practice can improve their injection rates through a similar step-wise process. Second, we assessed injection rates as a surrogate for image quality, thus relying on prior evaluations to imply clinical significance to our findings [1].

In summary, using a 19 G port access needle, larger inner diameter connector tubing and warm contrast media markedly improved our power port injection rates, which now achieve injection rates up to the device manufacturer specifications.

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Figure 1.

Graph shows the results of ex vivo port apparatus testing with maximum obtained injection rates without reaching 300 psi pressure limitation.

Note— psi-pounds per square inch; Baseline: 20 G vendor A access needle, 1.524 mm inner diameter tubing, room temperature contrast; Combination 1: 20 G vendor A access needle, 1.77 mm inner diameter tubing, room temperature contrast; Combination 2: 20 G vendor B access needle, 1.77 mm inner diameter tubing, room temperature contrast; Combination 3: 19 G vendor B access needle, 1.77 mm inner diameter tubing, room temperature contrast; Combination 4: 19 G vendor B access needle, 1.77 mm inner diameter tubing, 37° C warmed contrast.

Figure 2.

Graph of study group patient injection data at baseline and with the use of new port injection apparatus after process improvement. Despite significantly higher injections rates, the new injection process only had 12% of injections with pressure limitation at 300 psi compared with 19% at baseline.

Figure 3.

Axial contrast-enhanced CT images and associated injector pages from the same patient at baseline (A) and after the step-wise port injection apparatus changes (B). The baseline scan (A) demonstrates a typical pressure limiting injection our practice often encountered prior to the process improvement. Markedly improved arterial enhancement without pressure limitation can be seen on the scan performed with the new injection apparatus (B).